Electron ID projections

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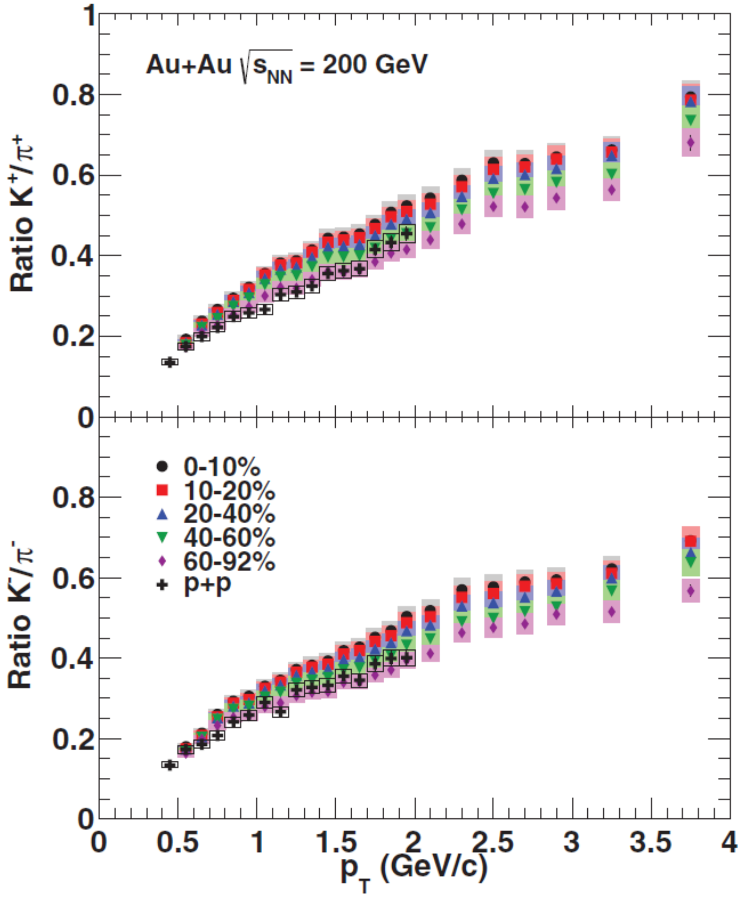
Software tools

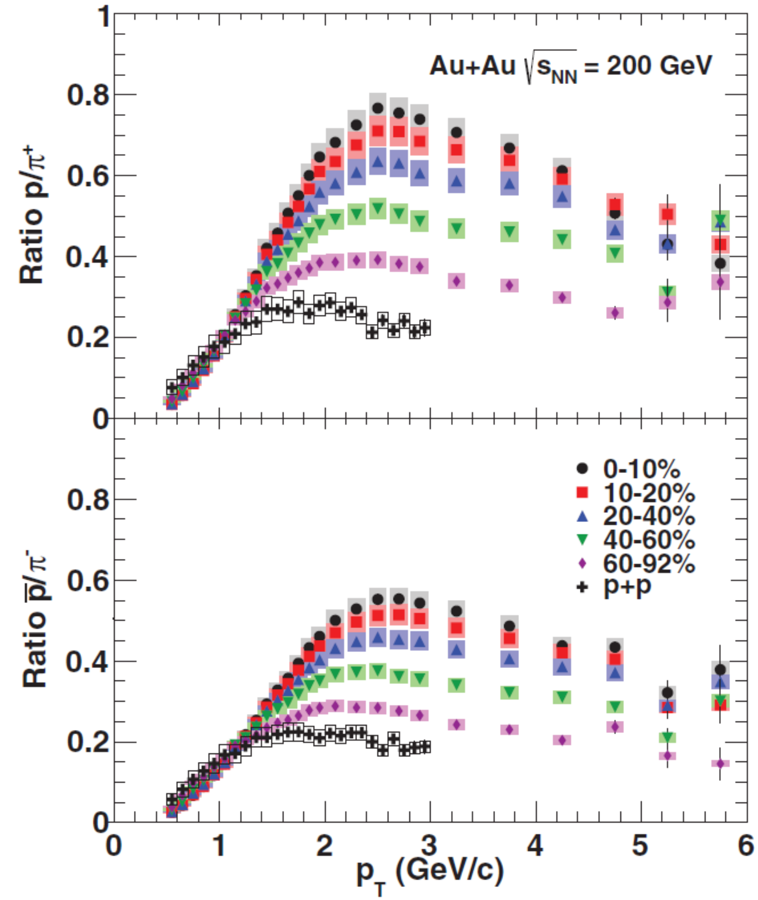
- Software: in analysis repository
  - https://github.com/sPHENIX-Collaboration/analysis/tree/master/EMCal-analysis
  - Fun4All analysis module to build condensed DST objects
    → pico-DST file of emcal focused analysis
- Procedure:
  1. From a truth particle
  2. -> Find best track (cut on good track)
  3. -> Project to calorimeters
  4. -> Build cluster around the track projection, w/ projection, p, eta dependency
  5. -> Use half sample to extract PDF distribution of (Inner Hcal, E/p)
  6. -> Apply PDF to the other half of stat. to calculate likelihood for electron/hadron and make rej/eff curve with a cut on likelihood difference
  7. -> Use measured pi/K/p ratio to make merge into total hadron rejection
  8. -> Shower shape – demonstrated, not to use in design stage
- Analysis module :
  - EMCal-analysis/EMCalAna: track projection, clustering, truth association
    Mike's evaluator tool are very useful in trace between truth and reco track/towers
  - EMCal-analysis/EMCalLikelihood: assign log-likelihood to track-cluster pairs
- Plot macros: EMCal-analysis/macro

Hijing background: hadron composition

Phys. Rev. C 88, 024906 (2013)

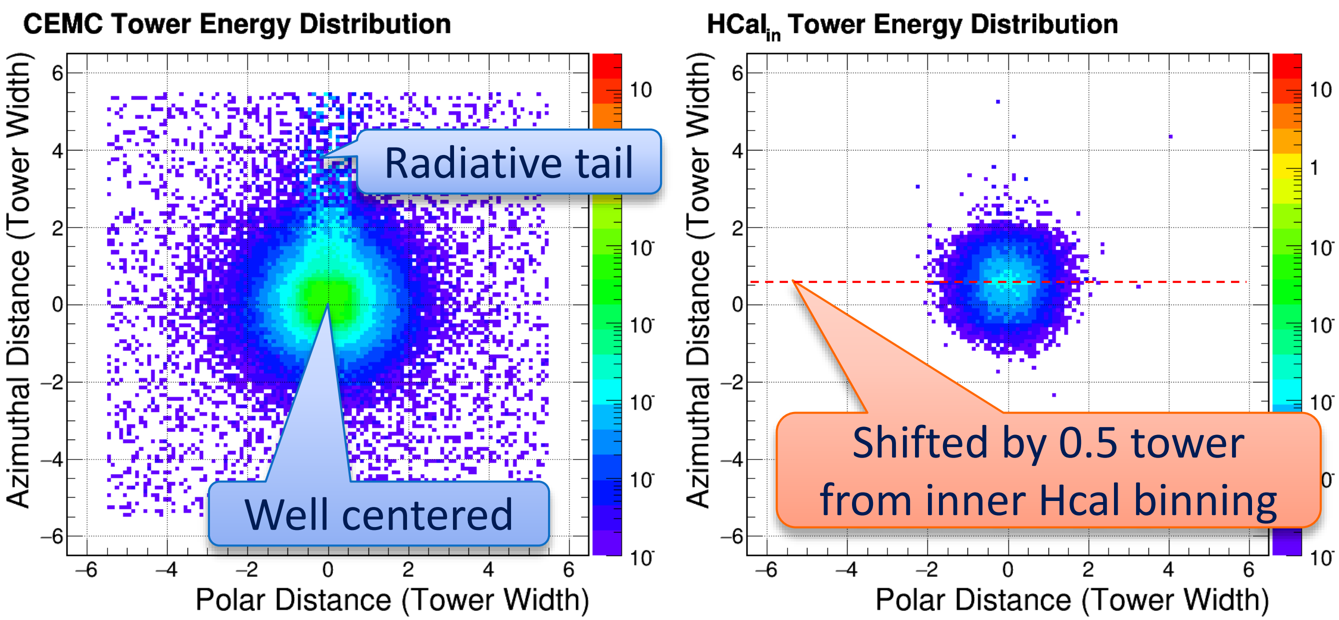
A.k.a. PHENIX/PPG146





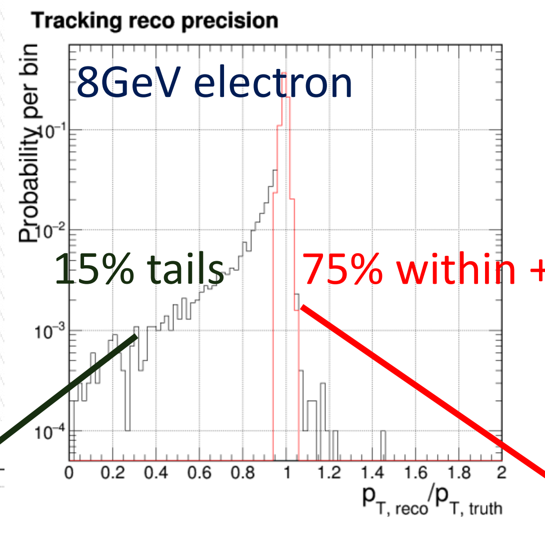
Shower distribution around the track

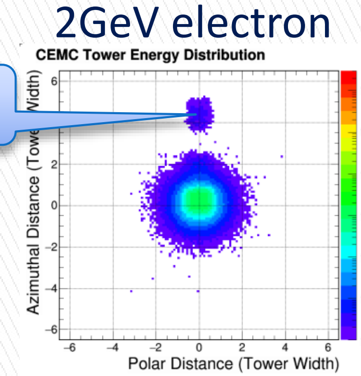
- In discussion about current problem:
  - https://github.com/sPHENIX-Collaboration/coresoftware/pull/69
  - Using this quick solution right now
- Result plot: 8GeV electron track projection to 2D projective SPACAL
- Not shown here though: with 8mm strip at last layer, projection is discretized to 2mm steps at a given vertex point

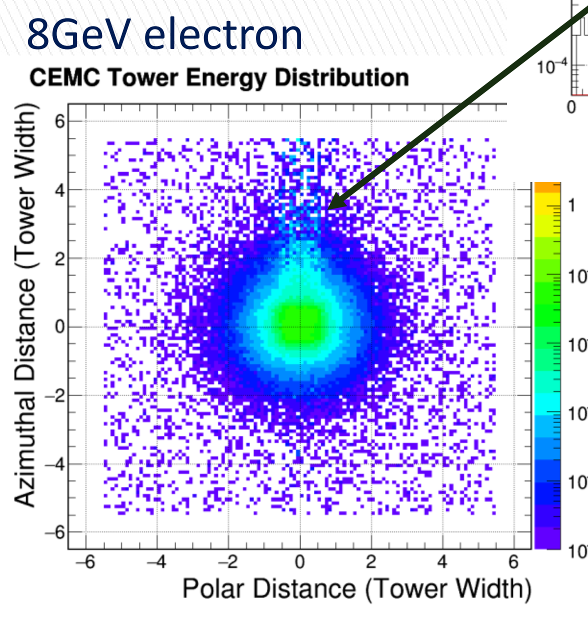


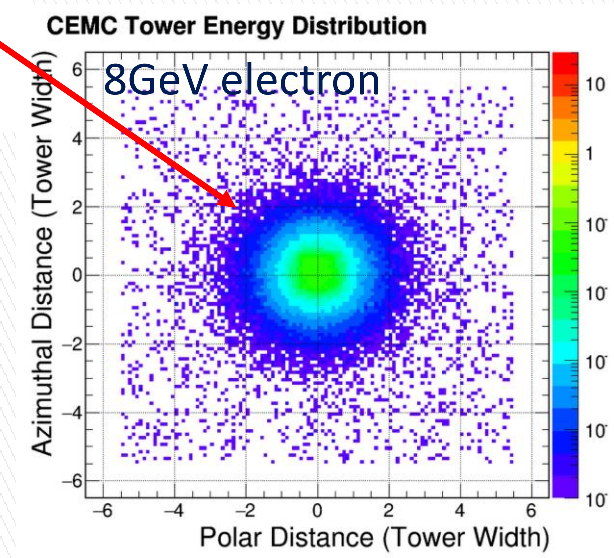
Track projection checks – Removing radiative tails

Full sPHENIX
Single electron + Geant4
+ digitization + Tracking









All reconstructed tracks

Track with pT reco within 5% of truth (sample for eID ana.)

Building cluster based on tower distance to the track production (+shift cor.)

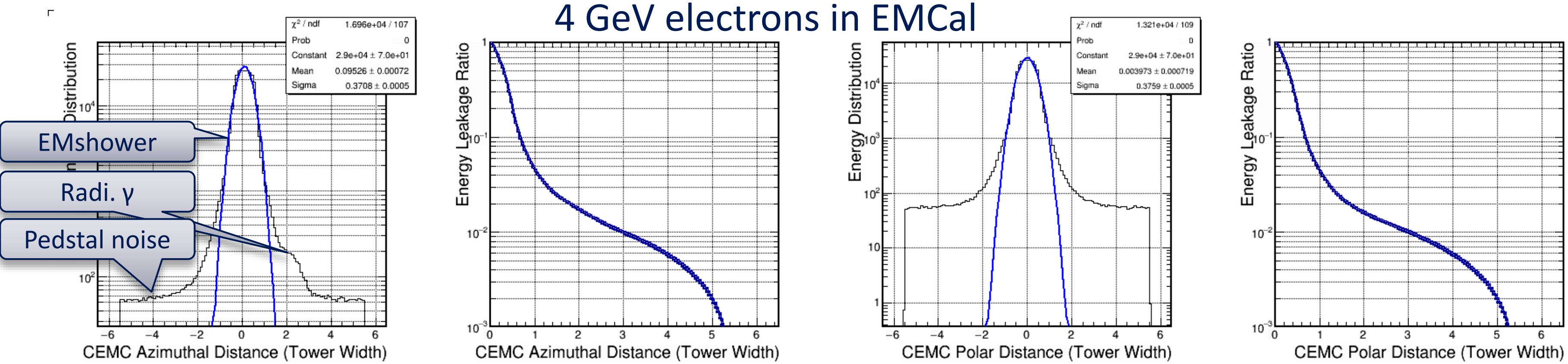
First choice of cluster radius cut is 1.6 tower width in both inner Hcal and EMCal

- 98% EM-shower containment in EMCal, 90% hadron shower containment in EMCal, 80% hadron shower containment in inner Hcal
- If shower hit around tower center, neighbor towers are included
- Average cluster size ~ 8 towers, similar but better than 3x3-tower cluster

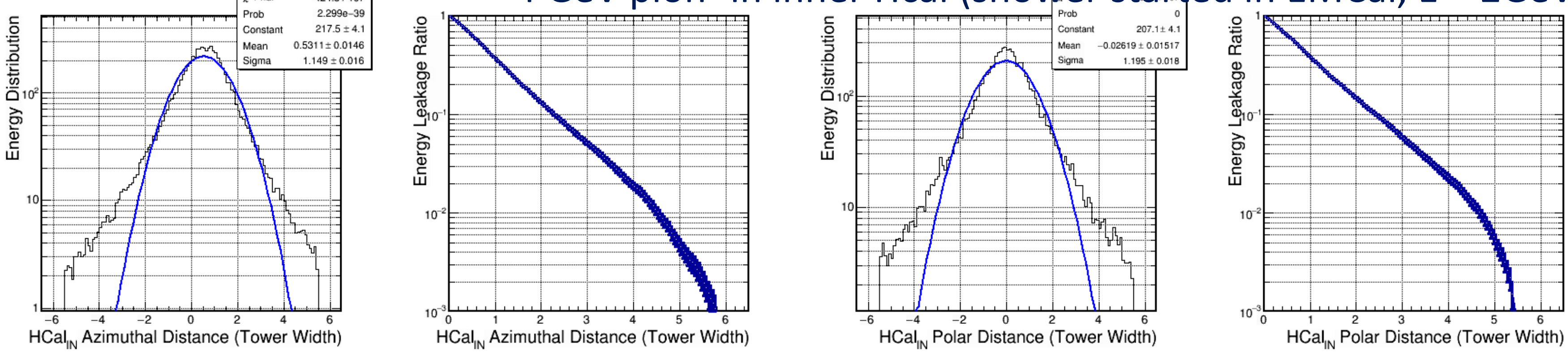
A tighter cluster radius would further balance reduction of HI background VS leakages (shower size/mismatches, etc.)

Then find cluster center for other momentum, charge, eta-bin and SPACAL configuration too.

4 GeV electrons in EMCal



4 GeV pion- in inner Hcal (shower started in EMCal, E > 2GeV)

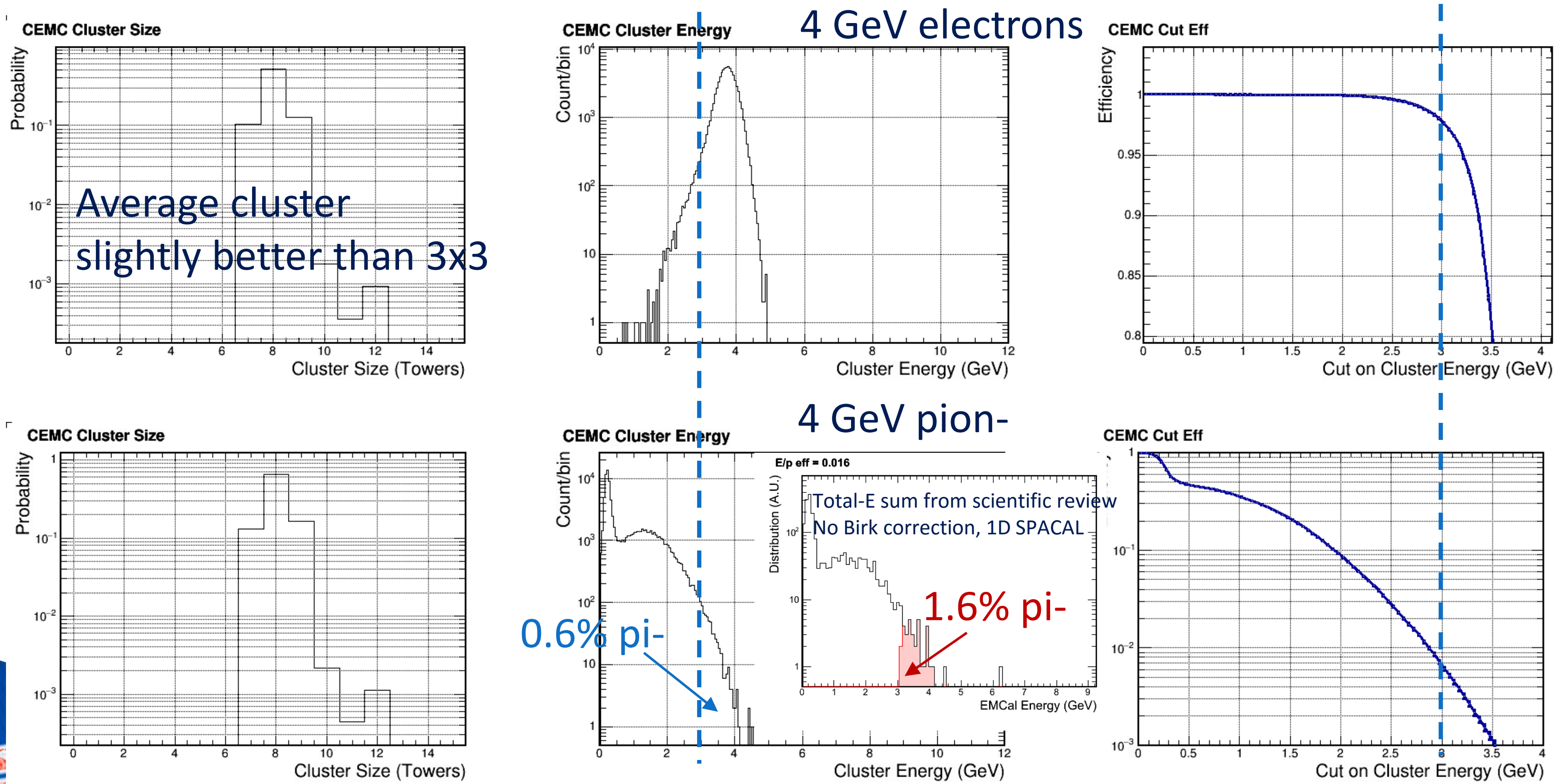


Electron ID in single particle simulations

Cluster energy matching, EMCal only

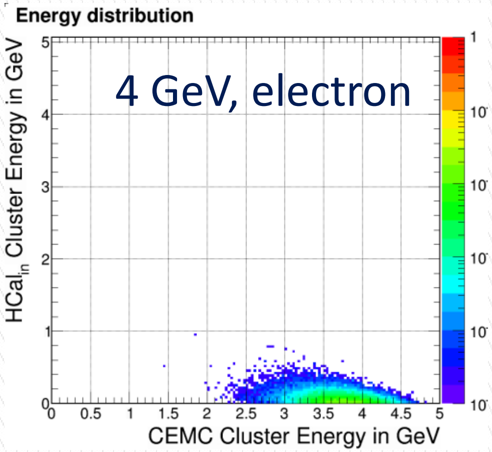
Single particle 4 GeV shower in 2D proj. SPACAL @ eta=0

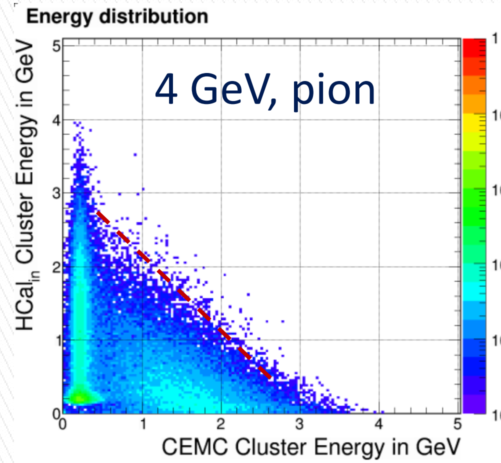
- Simple EMCal cut to illustrate expected performance
- Significant improvement for Birk correction
  - Pion tail reduced from ~ 1.6% to 0.6%

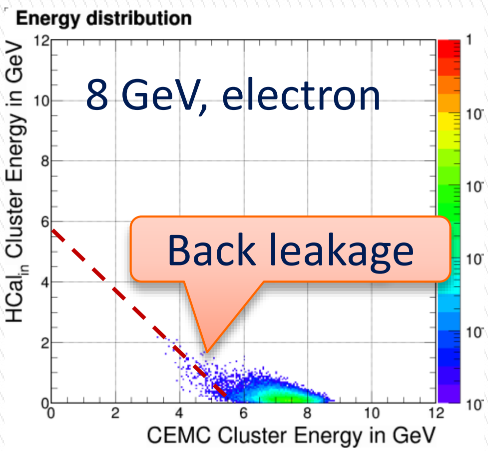


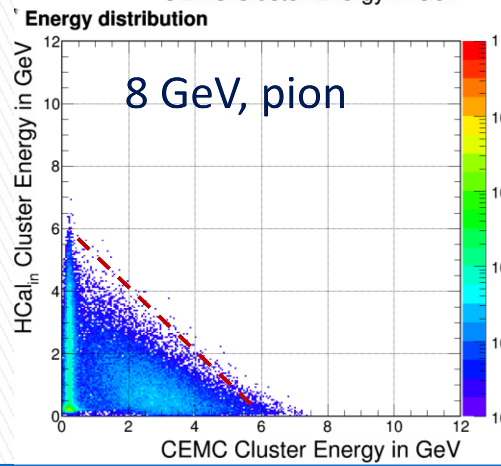
Energy matching with inner HCal

Single particle 4/8 GeV shower in 2D proj. SPACAL @ eta=0







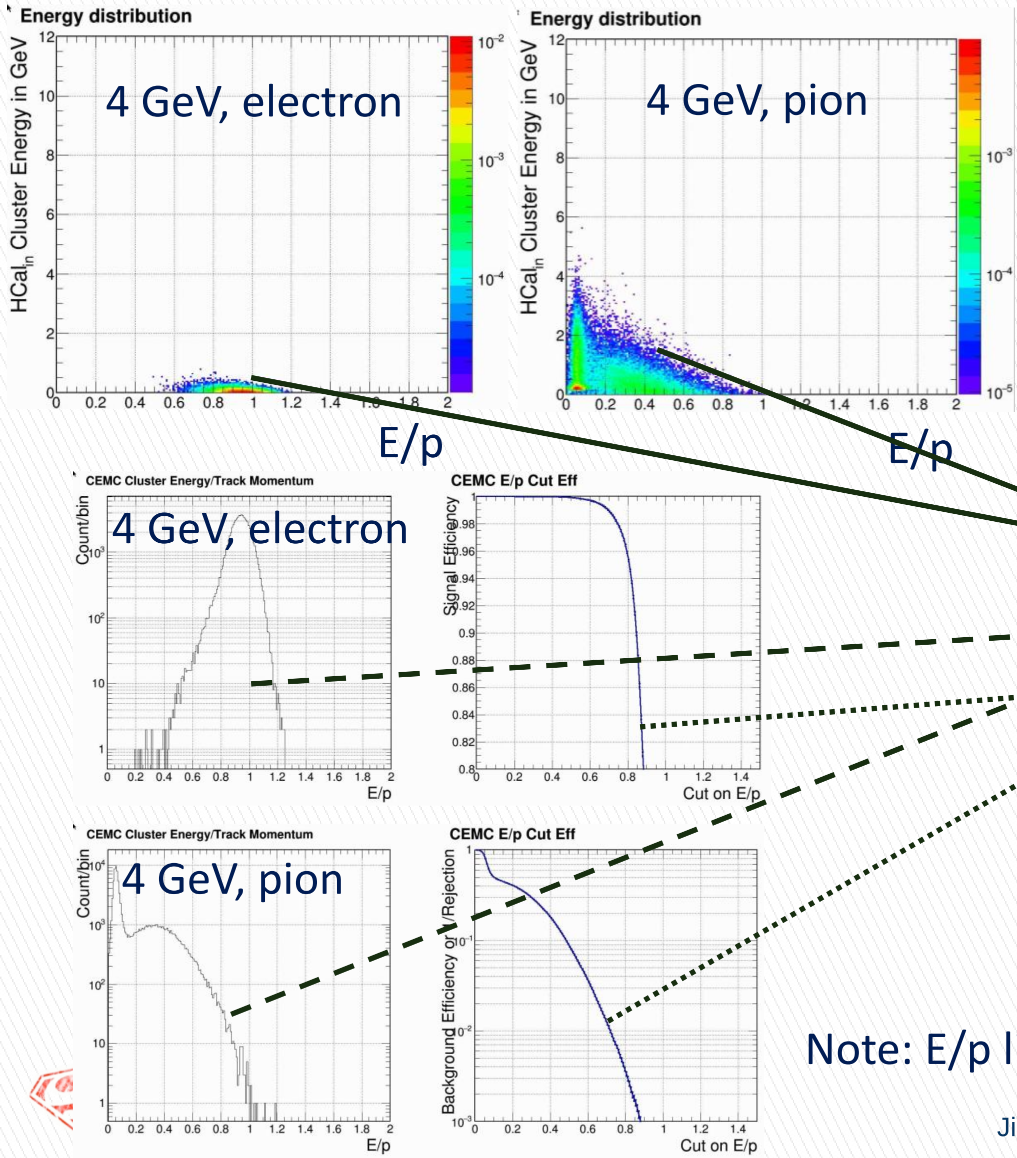


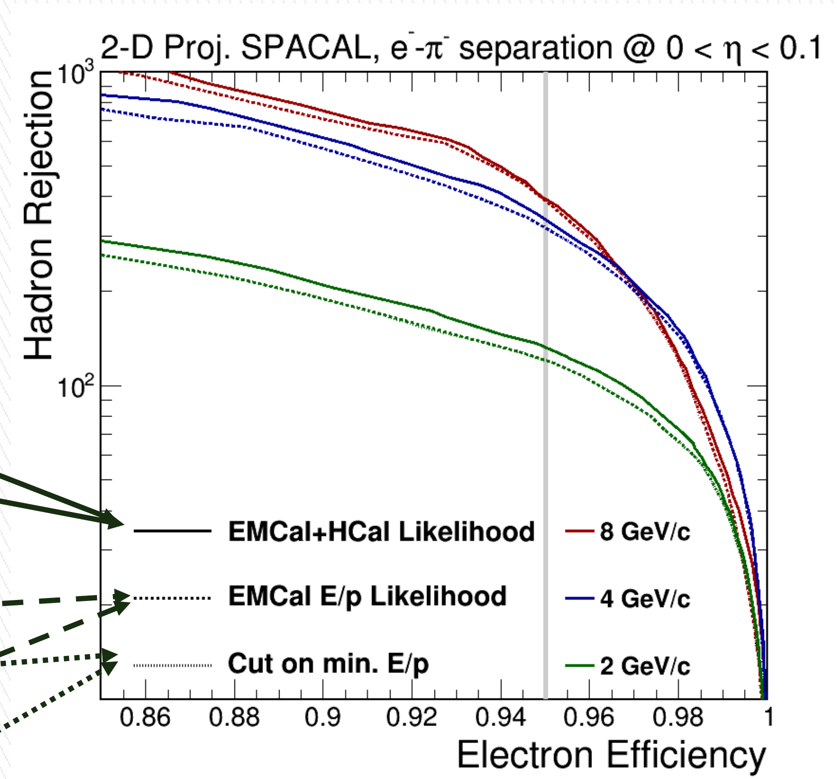
Electron,
anti-radiative cut dp/p<5%

Pion

E/p analysis methods comparison

Single particle 2/4/8 GeV shower in 2D proj. SPACAL @ eta=0



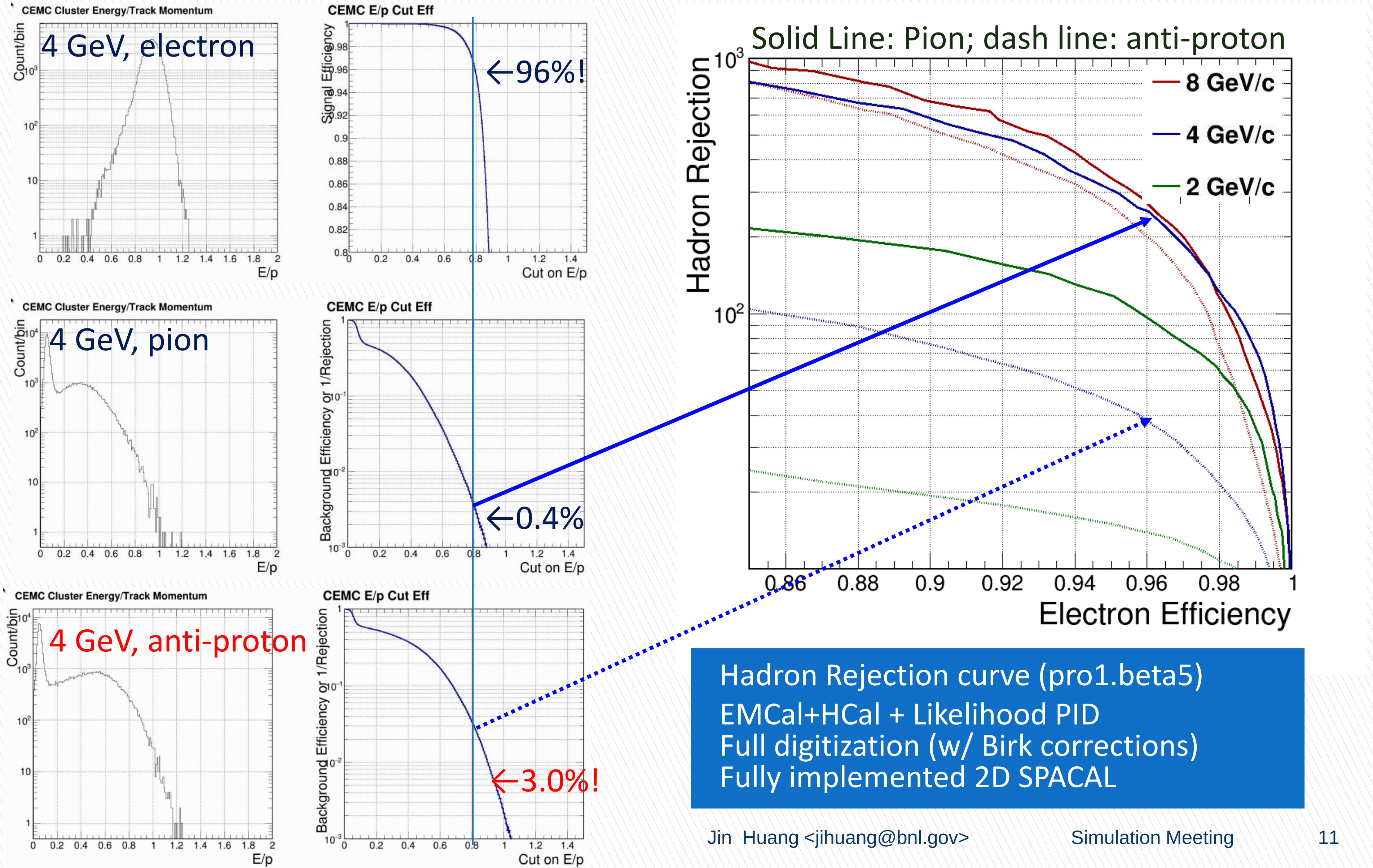


Pion Rejection curve (pro1.beta5)
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

Note: E/p likelihood ≈ cut on min E/p

Anti_proton component

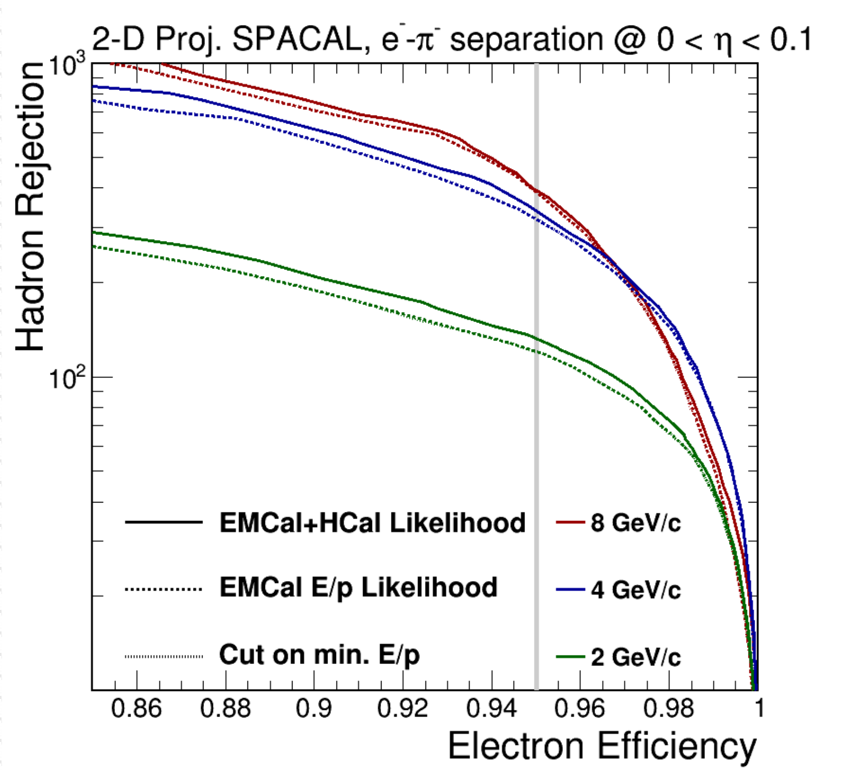
Single particle 2/4/8 GeV shower in 2D proj. SPACAL @ eta=0

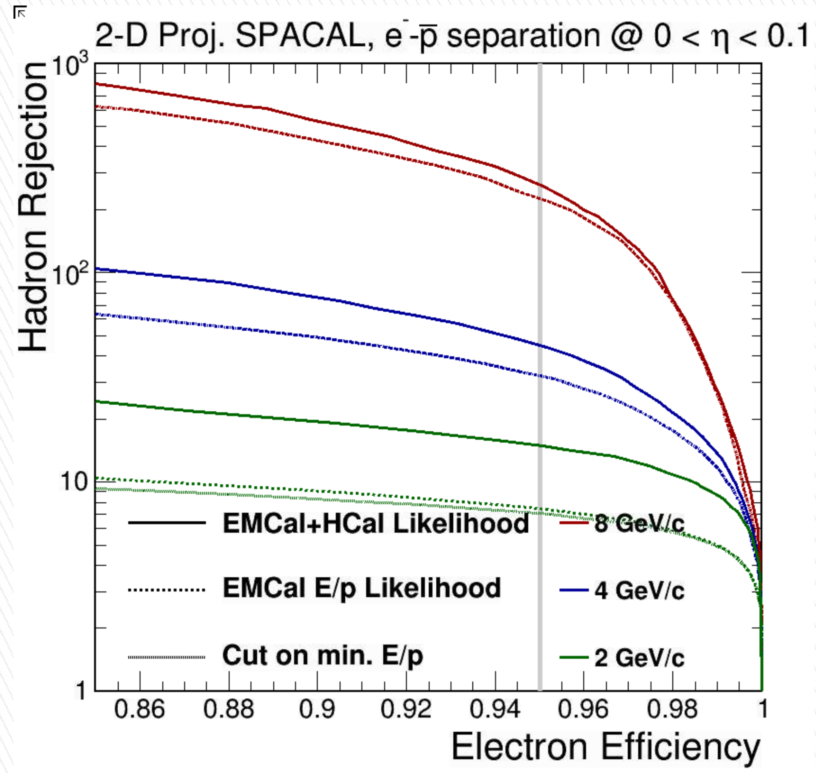


Hadron Rejection curve (pro1.beta5)
EMCal+HCal + Likelihood PID
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

Inner Hcal is more useful in rejecting Anti_proton (x2 at lower energy)

Single particle 2/4/8 GeV shower in 2D proj. SPACAL @ eta=0



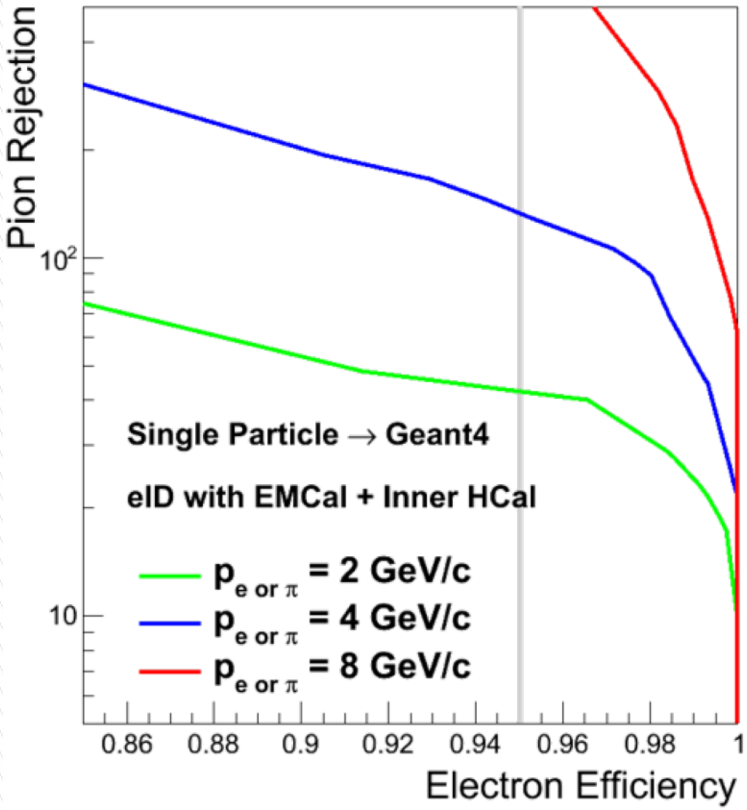


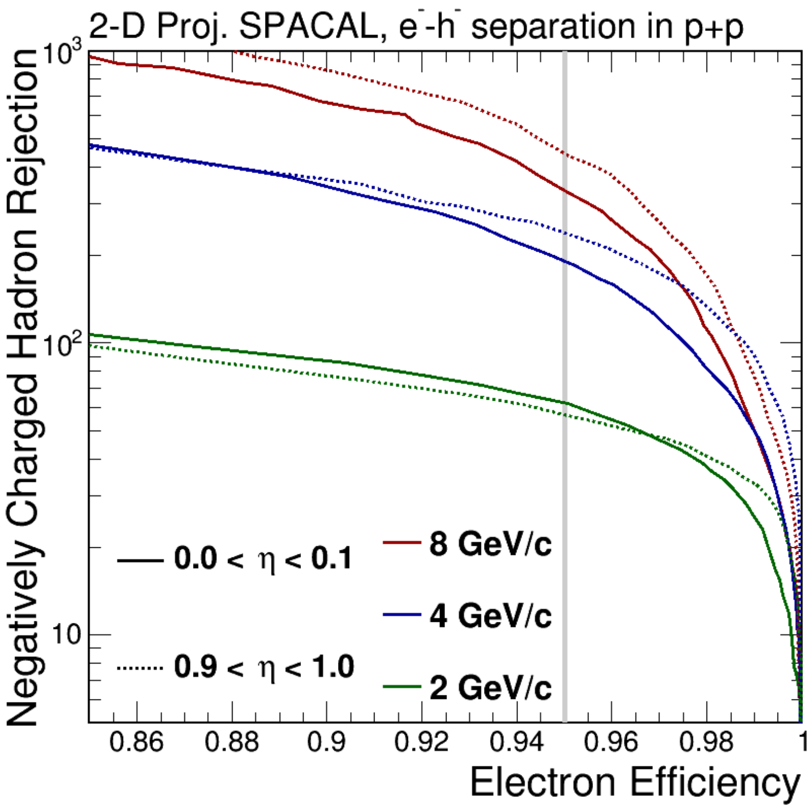
Pion Rejection curve (pro1.beta5)
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

Anti-proton Rejection curve (pro1.beta5)
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

Single Particle Summary: h-

Single negatively charged particle 2/4/8 GeV shower in 2D proj. SPACAL





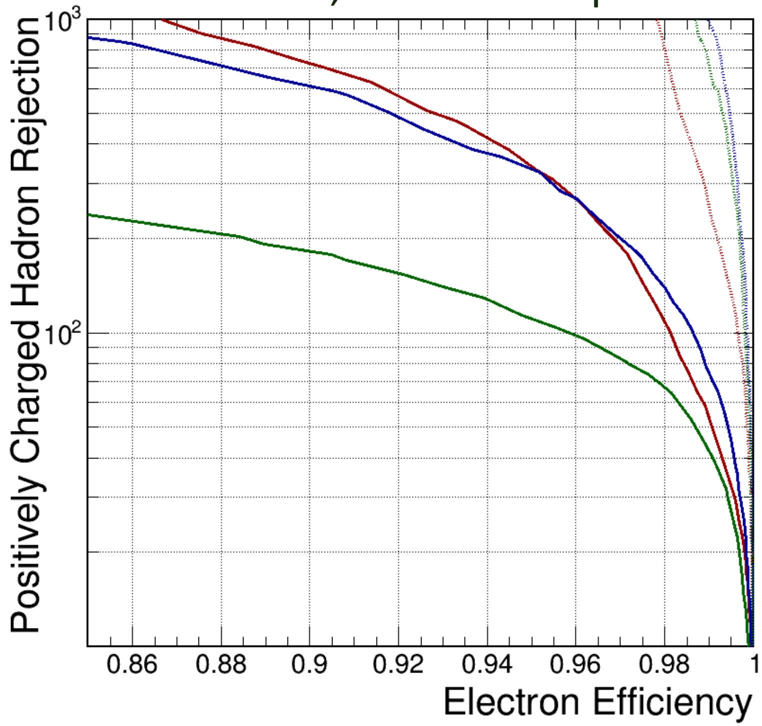
Scientific review plot
Sum all scintillator energy (w/o Birk Cor.)
1D SPACAL material cut into 2D SPACAL towers

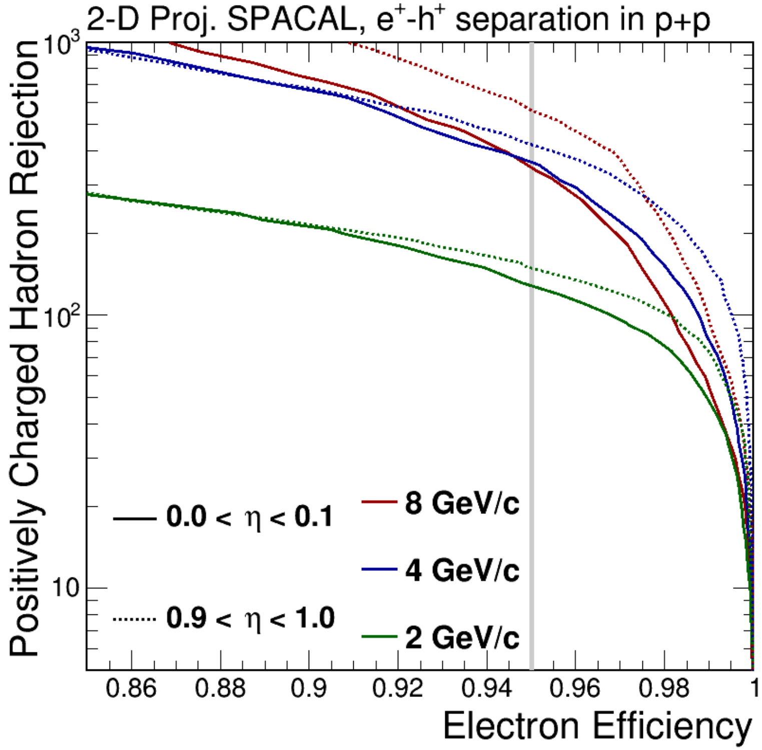
New plot (pro1.beta5)
Sum all hadron taking account of hadron ratio
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

Single Particle Summary: h+

Single positively charged particle 2/4/8 GeV shower in 2D proj. SPACAL @ eta=0

Solid Line: Pion; dotted line: proton





Particle separated @ eta = 0

Sum all hadron taking account of hadron ratio
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

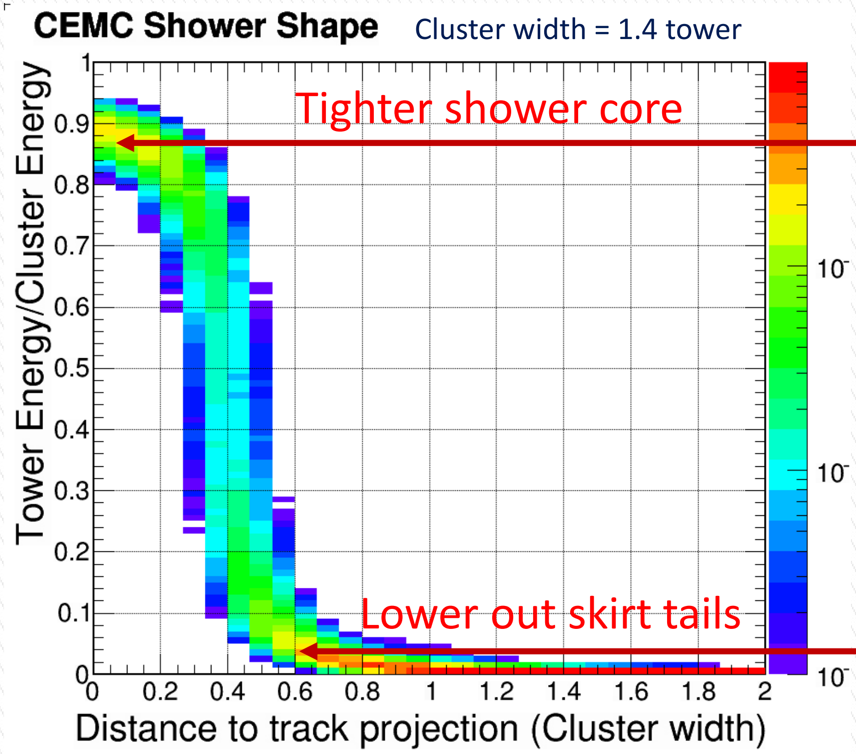
Summary

Sum all hadron taking account of hadron ratio
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

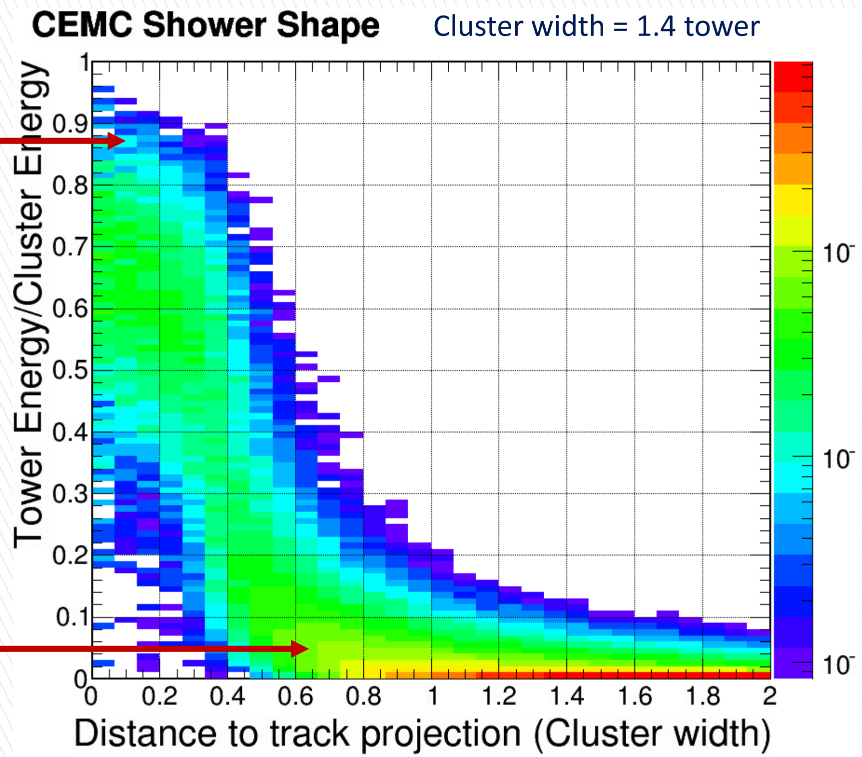
Beyond energy sums: shower shape

Single particle 8 GeV shower in 2D proj. SPACAL @ eta=0

- Beyond cluster energy deposition, one can build a likelihood based on shower shape
- But we try not relying on it during design stage, as it is more relying on simulation accuracy



Electron shower

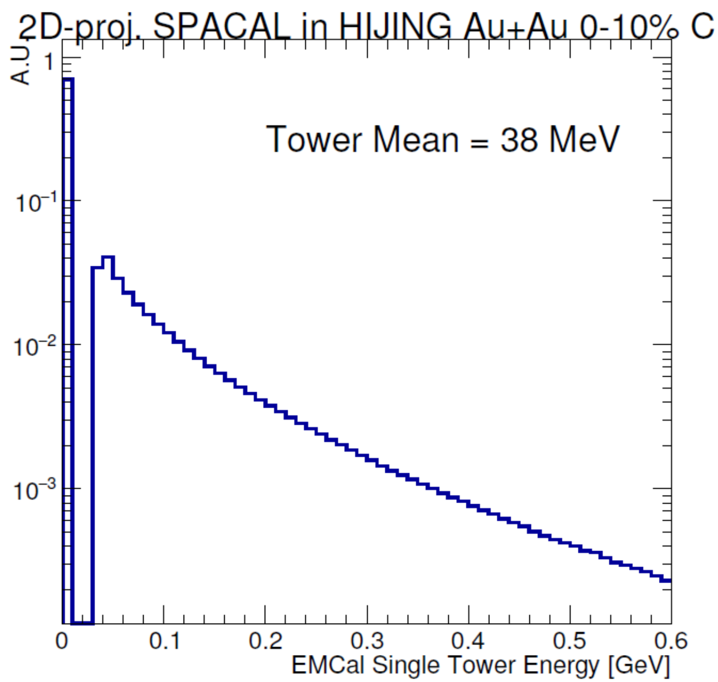


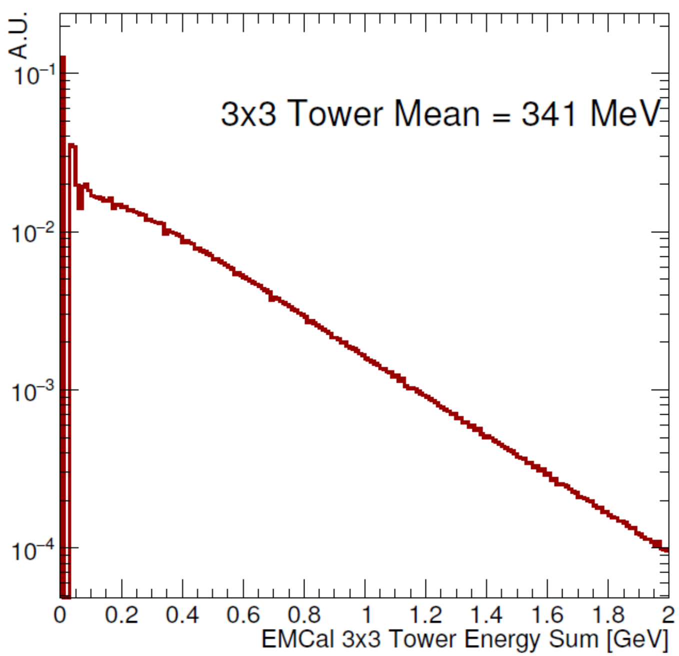
Pion shower (E>3 GeV)

Central Hijing Embedded

Hijing background: energy deposition
10% Central Hijing in 2D proj. SPACAL @ eta=0

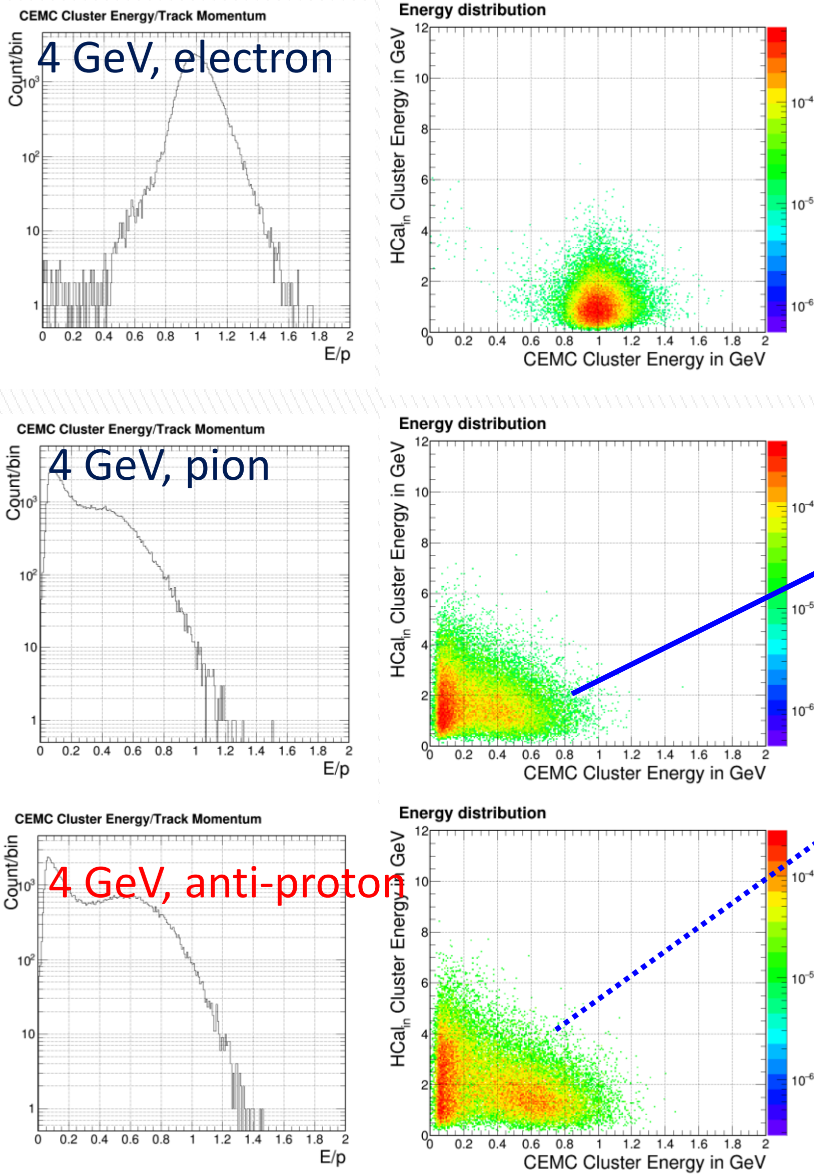
- Updated features (from scientific review.):
  - 32 MeV zero suppression
  - Reduced visible background from hadron due to Birk corrections
- 2D SPACAL shown. 1D SPACAL corresponding to 60% higher mean value in the forward due to larger cluster



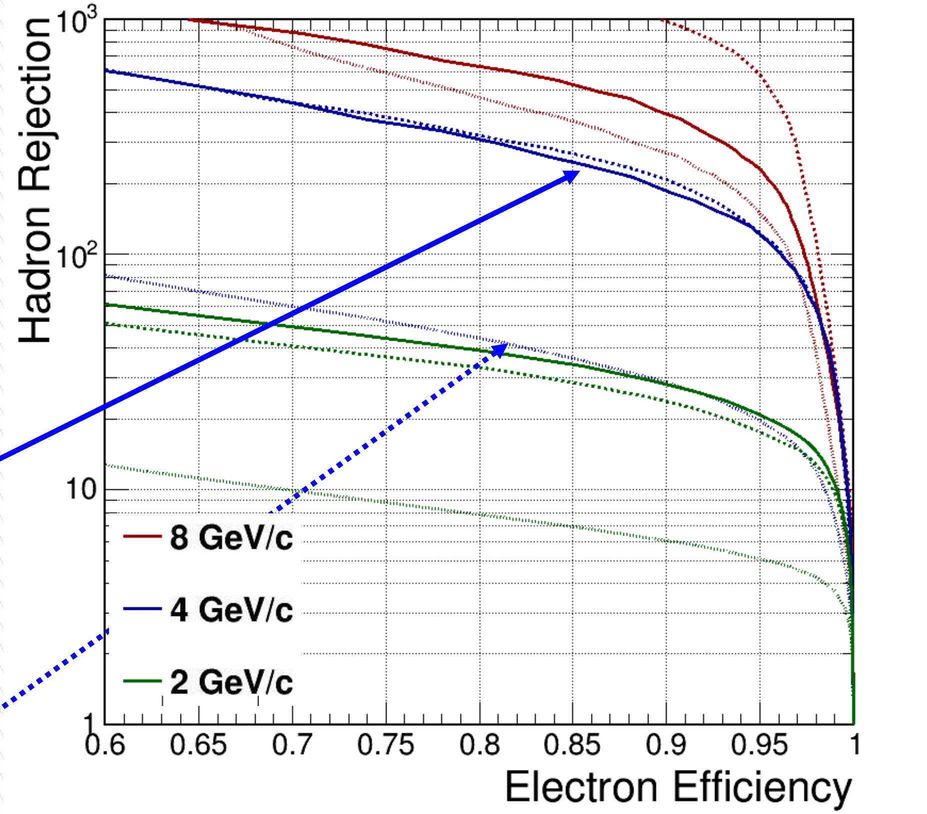


Particle ID depending rejection

10% Central Hijing embedding in 2D proj. SPACAL @ eta=0



Solid Line: Pion; dash: K-; dotted line: anti-proton



Hadron Rejection curve (pro1.beta5)

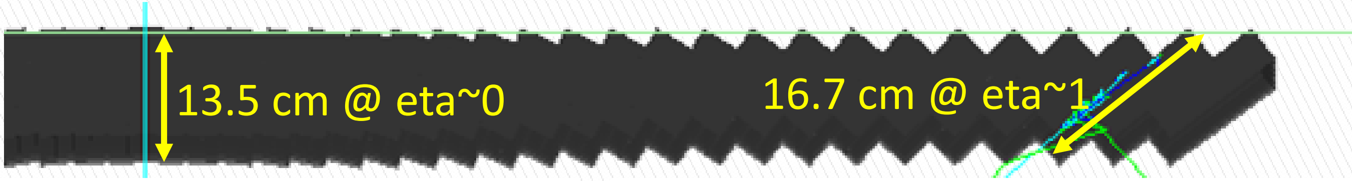
EMCal+HCal + Likelihood PID

Full digitization (w/ Birk corrections)

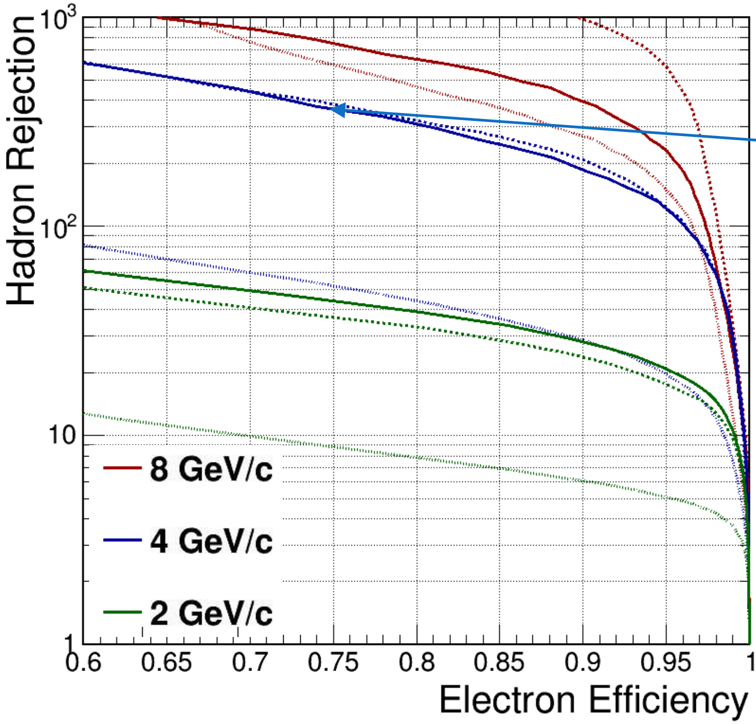
Fully implemented 2D SPACAL

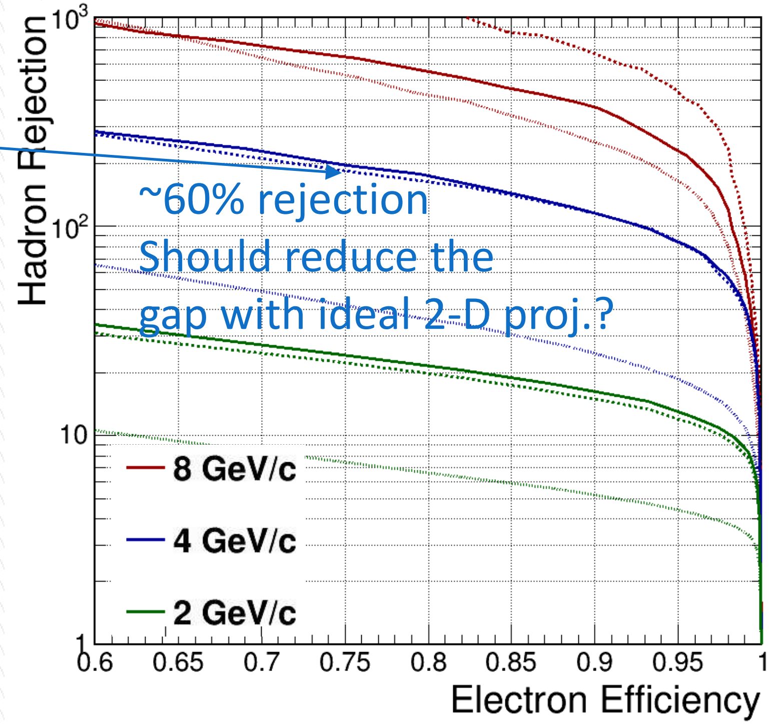
In Hijing, rapidity dependency

10% Central Hijing embedding in 2D proj. SPACAL @ eta=0/1



Solid Line: Pion; dash: K-; dotted line: anti-proton





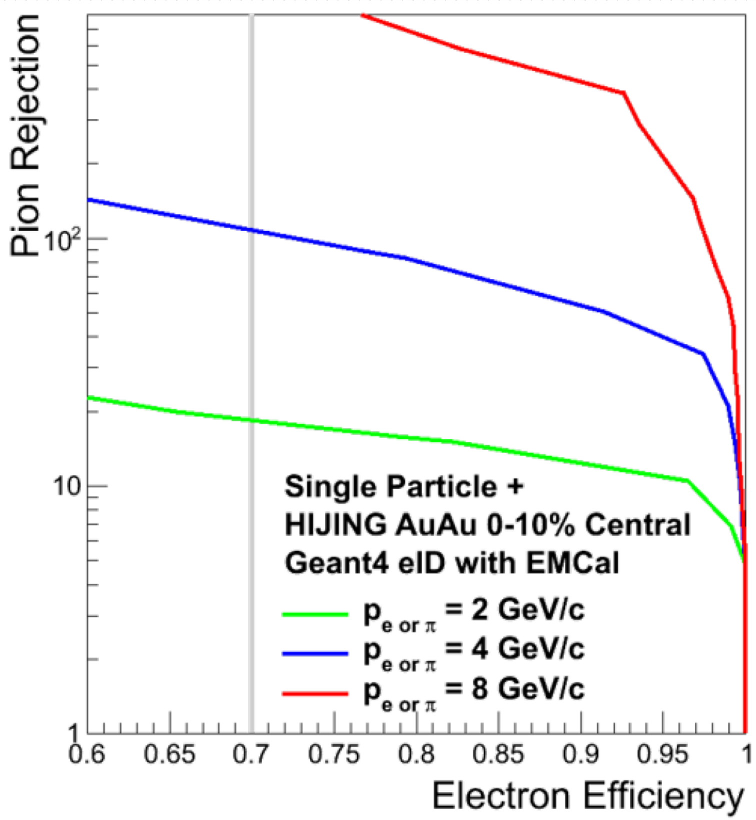
Eta = 0.0-0.1

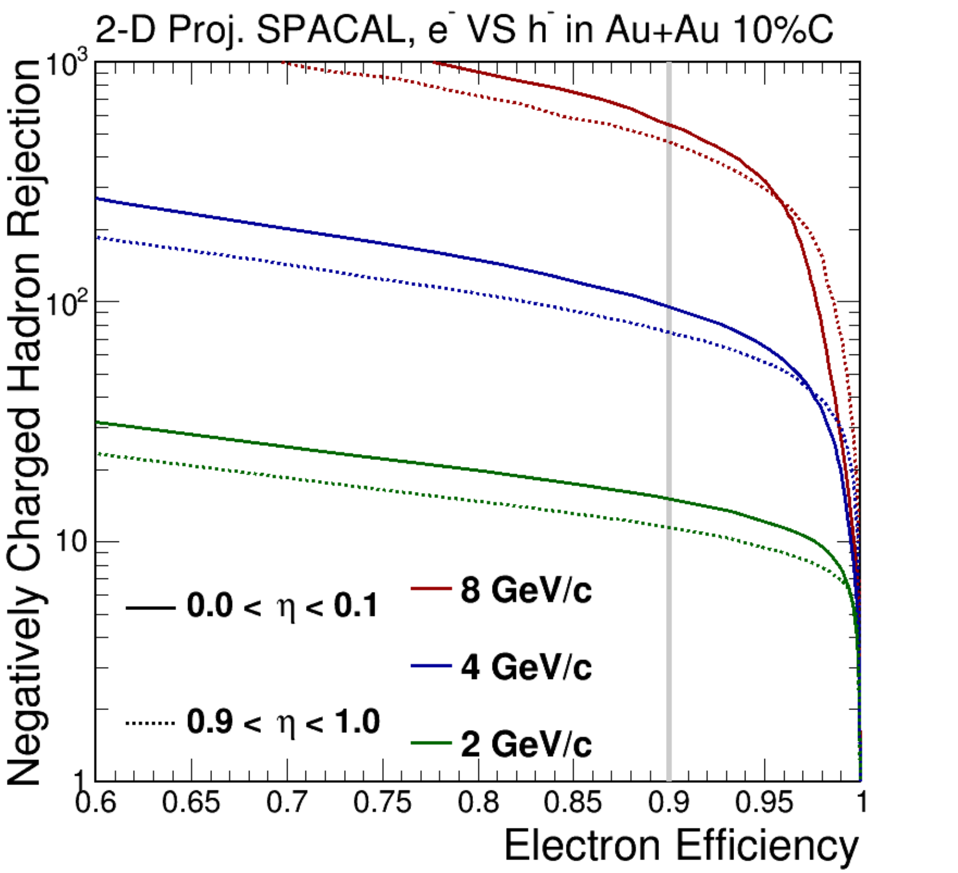
Eta = 0.9-1.0

In Hijing – 2D SPACAL summary: h-

10% Central Hijing embedding in 2D proj. SPACAL @ eta=0/1

Fully implemented 2D SPACAL structure also show a eta dependency (~1.5x)





Scientific review plot

Sum all scintillator energy
1D SPACAL material cut into 2D SPACAL towers

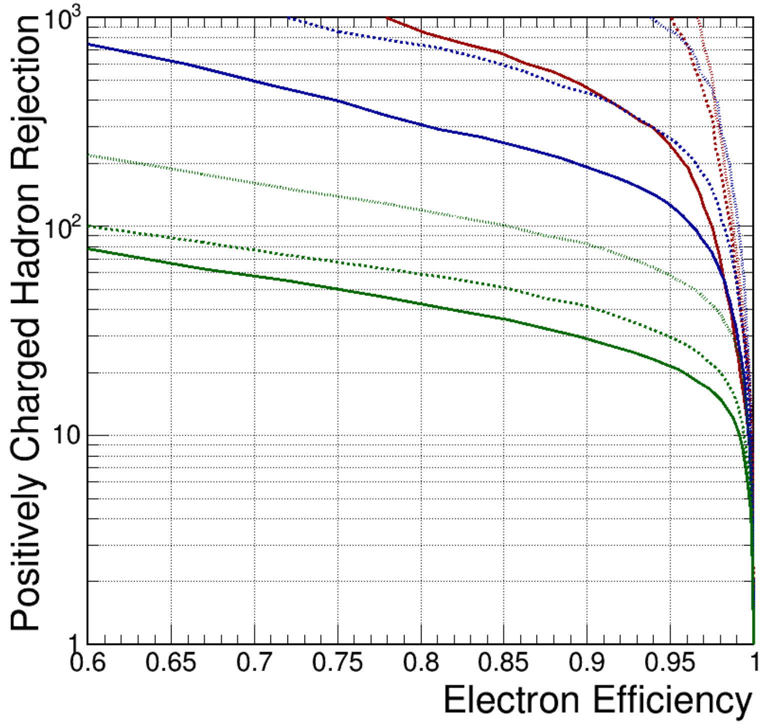
New plot (pro1.beta5)

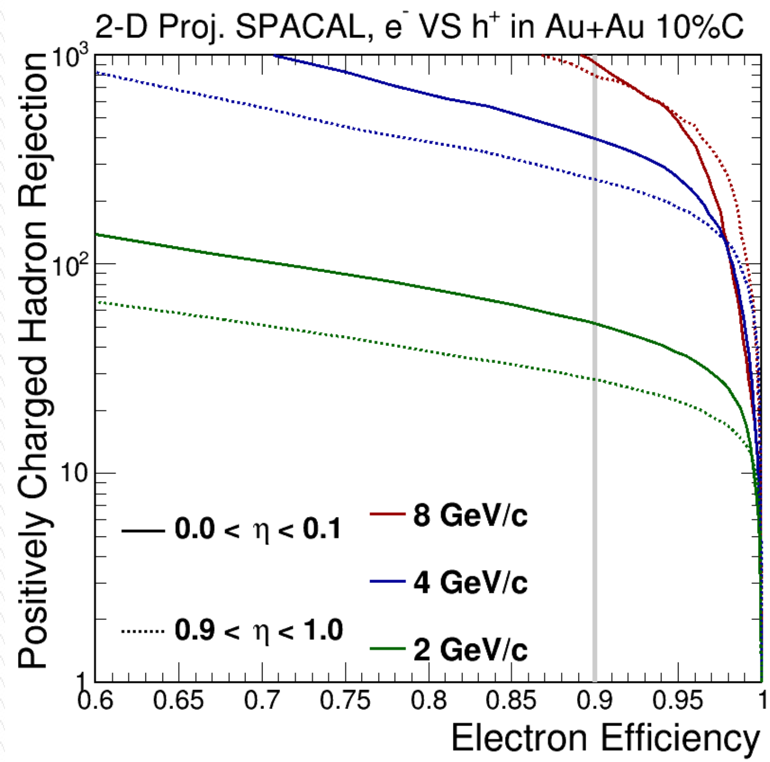
Sum all hadron taking account of hadron ratio
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

In Hijing – 2D SPACAL summary: h+

Single positively charged particle 2/4/8 GeV shower in 2D proj. SPACAL @ eta=0

Solid Line: Pion; dash: K+; dotted line: proton





Particle separated @ eta = 0

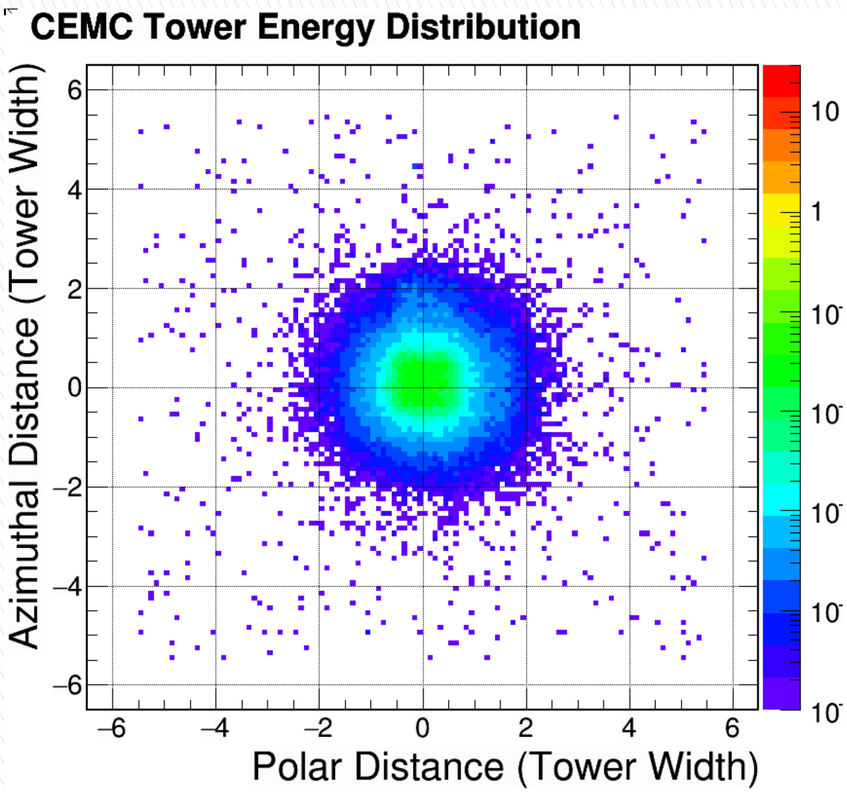
Sum all hadron taking account of hadron ratio
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

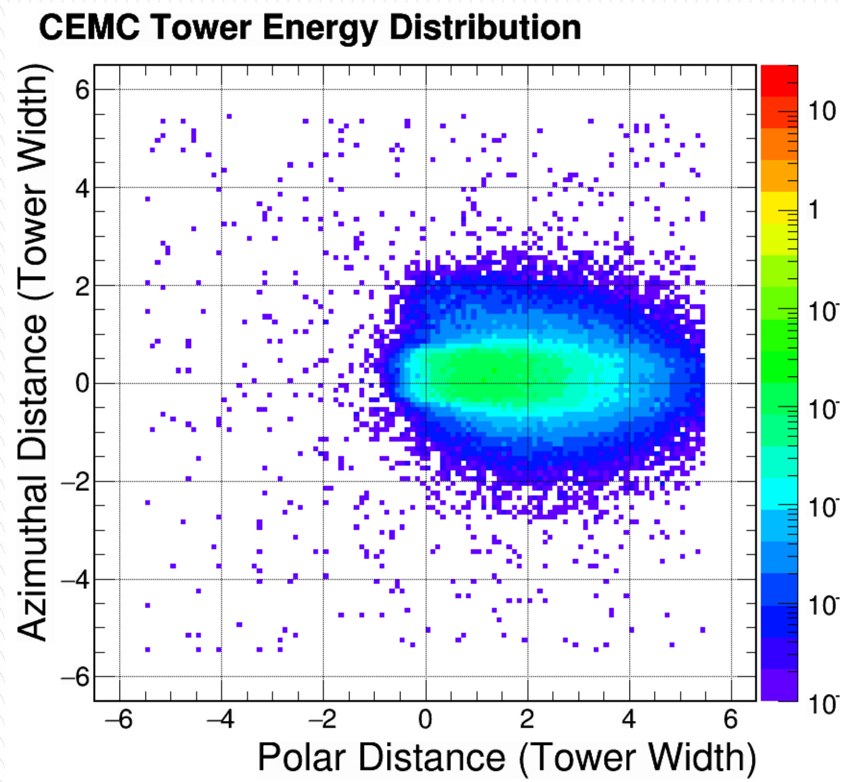
Summary

Sum all hadron taking account of hadron ratio
Full digitization (w/ Birk corrections)
Fully implemented 2D SPACAL

Shower distribution @ forward-most :

Single e- 8 GeV shower in 1D/2D proj. SPACAL @ eta=0.9-1.0





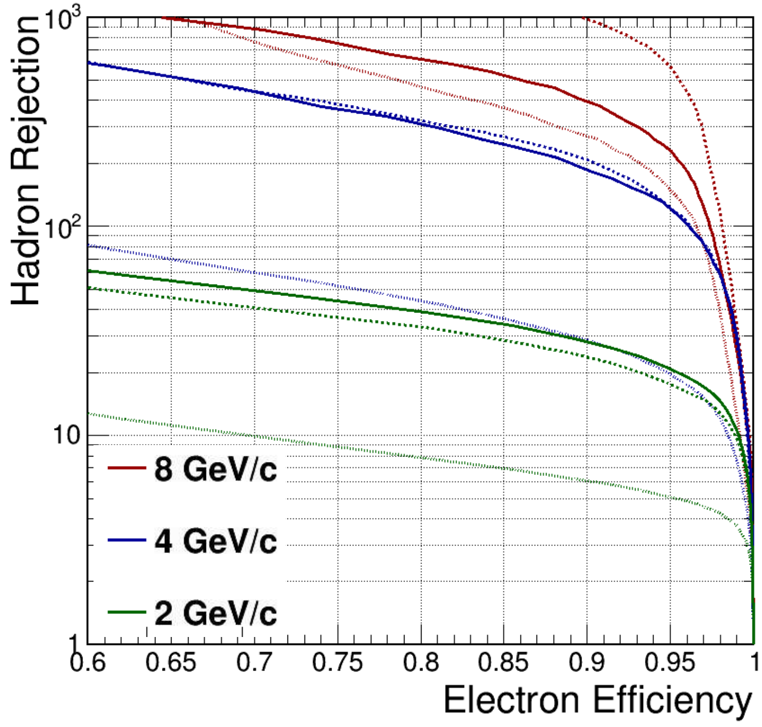
2D Spacal
Average cluster ~8 towers

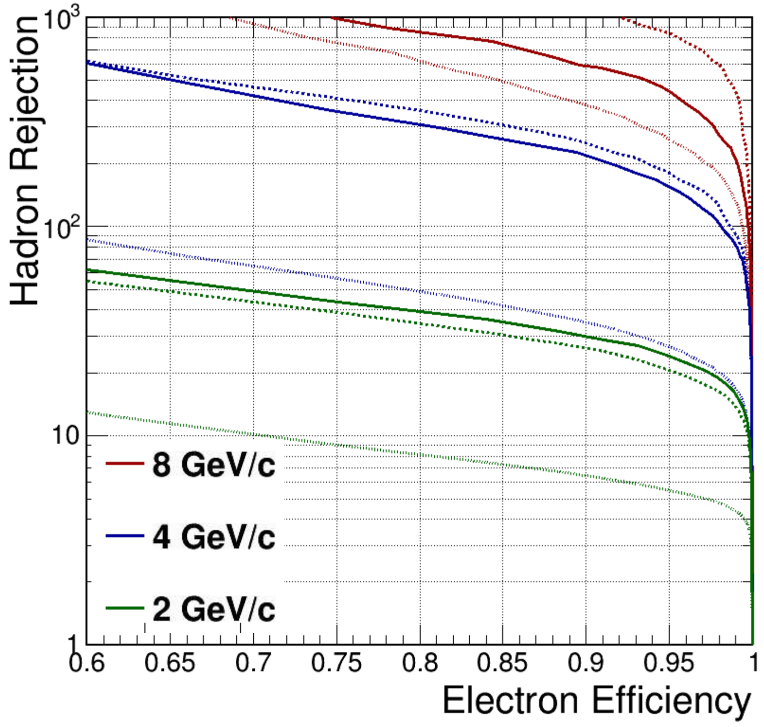
1D Spacal
Average cluster ~12+ towers

In Hijing, @ central rapidity

10% Central Hijing embedding in 1D proj. SPACAL @ eta=0-0.1

Solid Line: Pion; dash: K-; dotted line: anti-proton





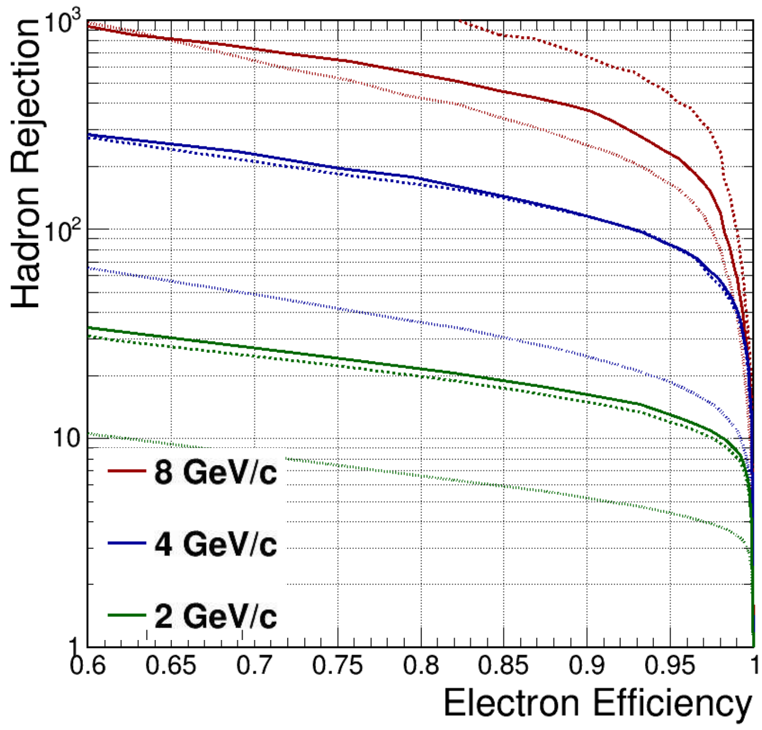
SPACAL 2D
With Birk corrections
Fully implemented 2D SPACAL

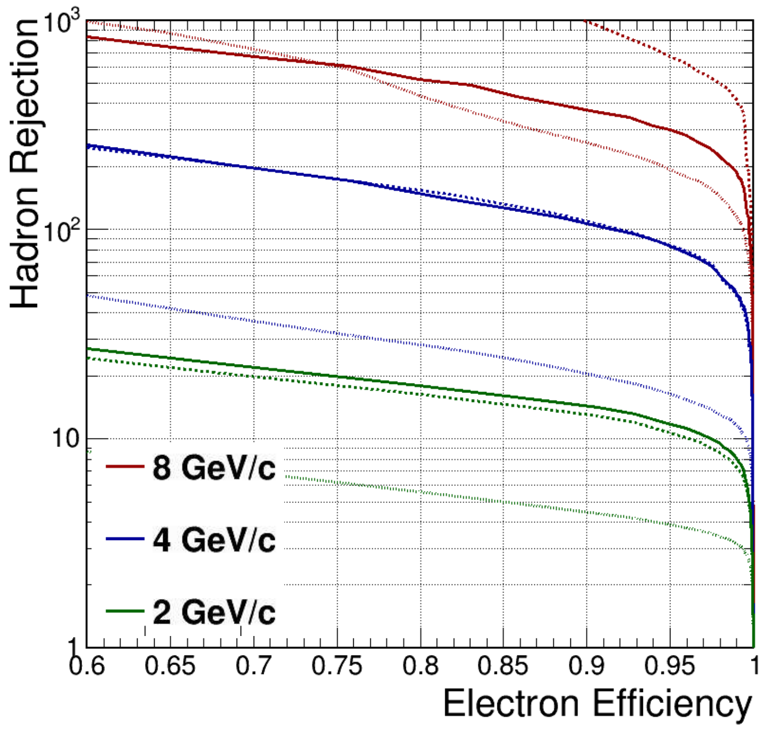
SPACAL 1D
With Birk corrections
Ideally implemented 1D SPACAL (no spt., no tower div.)

In Hijing, @ forward rapidity

10% Central Hijing embedding in 1D proj. SPACAL @ eta=0.9-1.0

Solid Line: Pion; dash: K-; dotted line: anti-proton



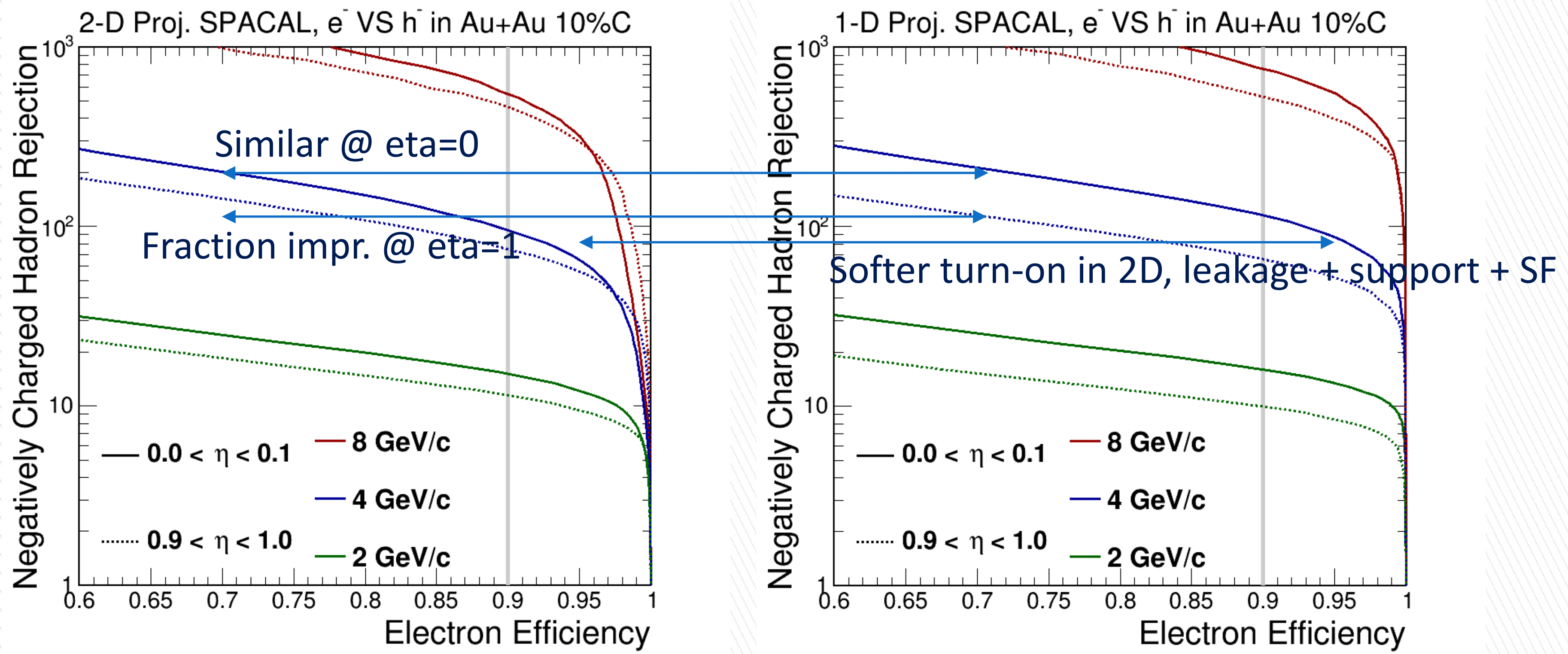


SPACAL 2D
With Birk corrections
Fully implemented 2D SPACAL

SPACAL 1D
With Birk corrections
Ideally implemented 1D SPACAL (no spt., no tower div.)

In Hijing – 1D VS 2D SPACAL summary: h-

10% Central Hijing embedding in 1D/2D proj. SPACAL @ eta=0/1



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SPACAL 1D
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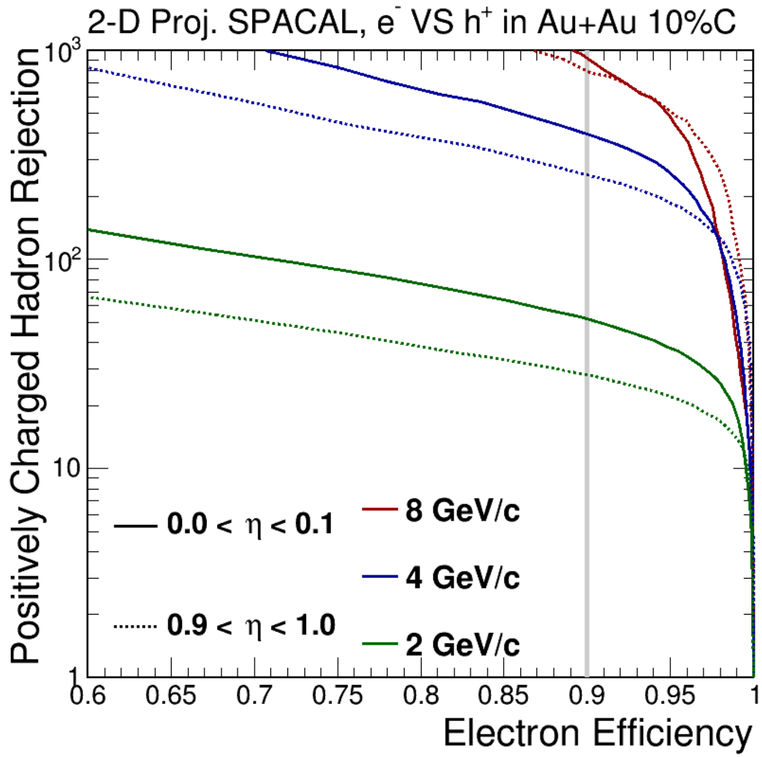
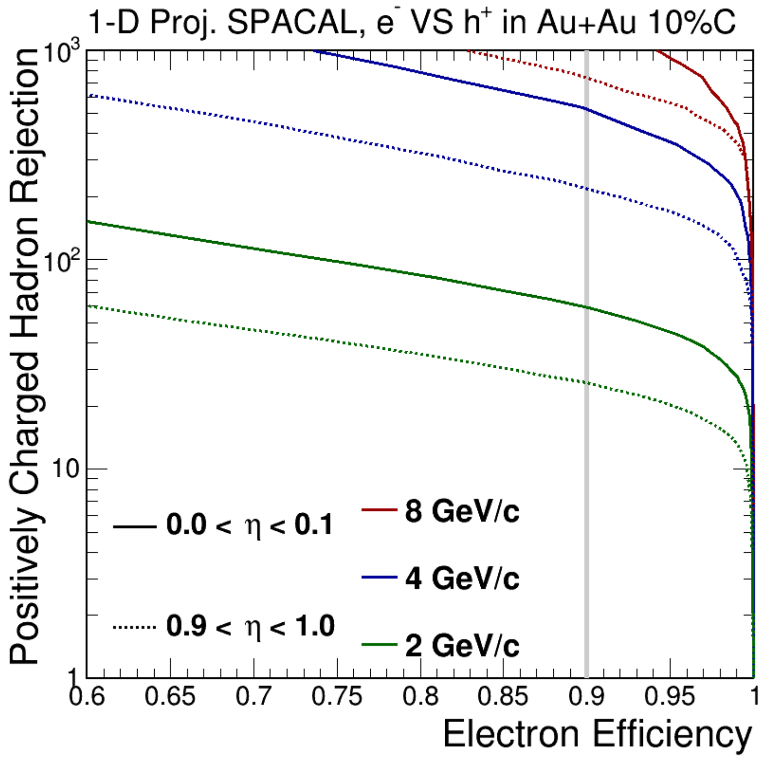
Ideally implemented 1D SPACAL (no spt., no tower div.)

In Hijing – 1D VS 2D SPACAL summary: h+

10% Central Hijing embedding in 1D/2D proj. SPACAL @ eta=0/1





SPACAL 2D
With Birk corrections
Fully implemented 2D SPACAL

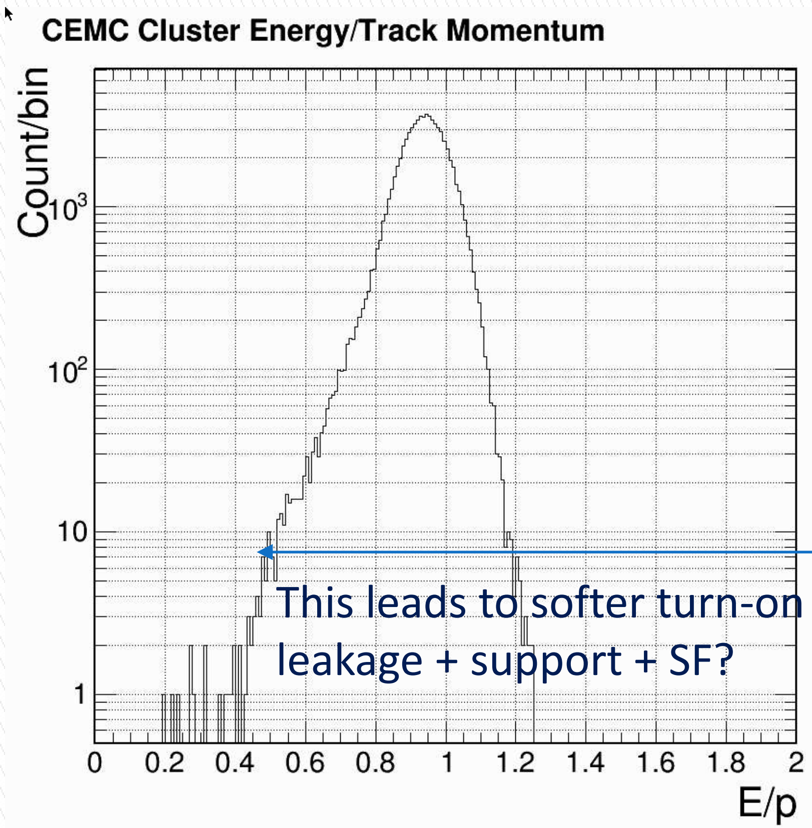
SPACAL 1D
With Birk corrections
Ideally implemented 1D SPACAL (no spt., no tower div.)

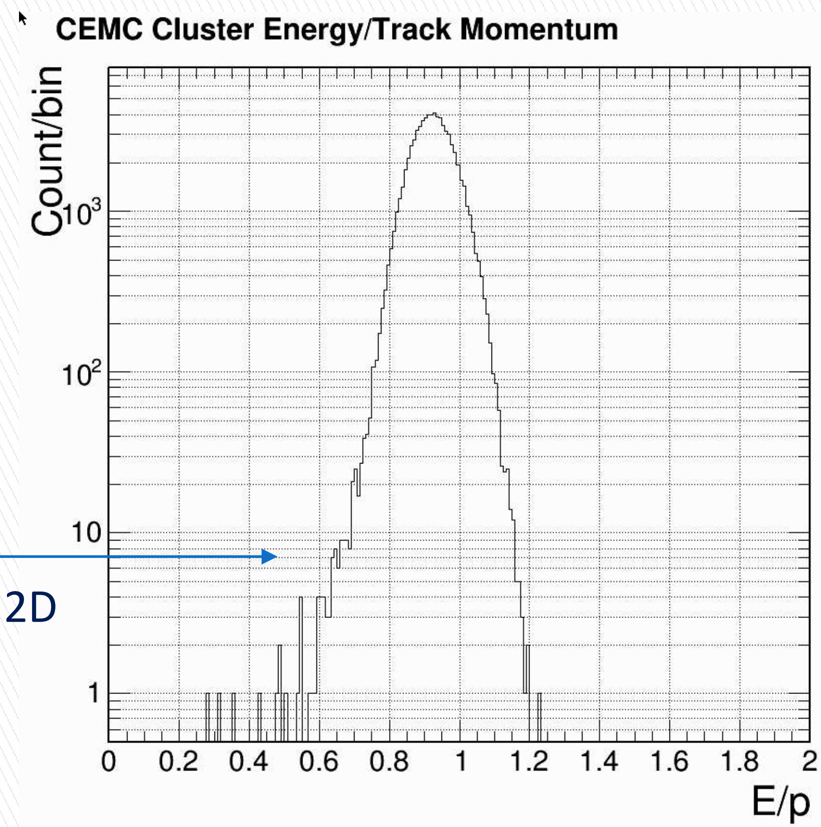
Summary

- Birk correction has large influence over hadron tails
  - Suppressed the h/e
  - Simple comparison showed x2-3 improvement in pp eID as the pion tail shifted to lower amplitude
- All options reach ~100:1 rej @ 90e eff. In central AuAu
- We went through a long way to implement 2-D projective design in detail to uncover its caveats: current 2-D projective SPCAL design also has rapidity dependency
  - Large longitudinal shift forced us use longer module
  - Recover ideal projective performance?
    - Use 1x8 modules and shorter modules.
    - Angled cut?
- 1-D VS 2-D?
  - Similar performance @ central pseudorapidity
  - Fraction improvement from 2-D @ forward pseudorapidity
- Inner Hcal is useful to verify the e-ID
  - Use for low momentum anti-proton case, bring x2 improvement
  - Verify EMCal e-ID for unforeseen background

Extra information

Single electron – 1D VS 2D SPACA

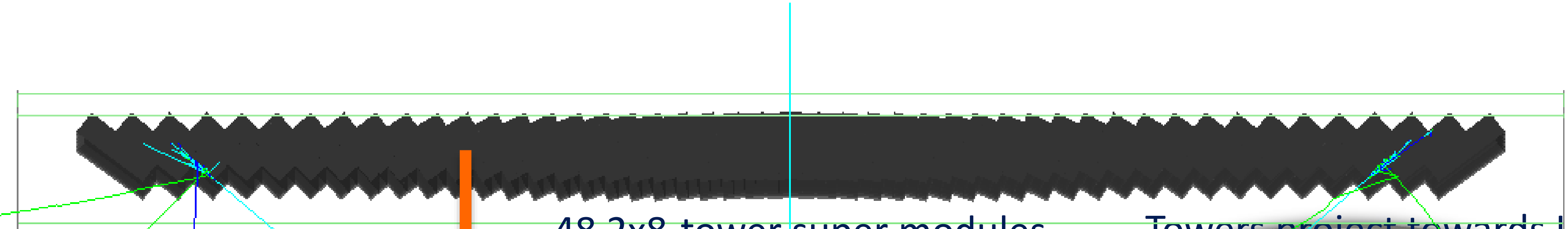




This leads to softer turn-on in 2D
leakage + support + SF?

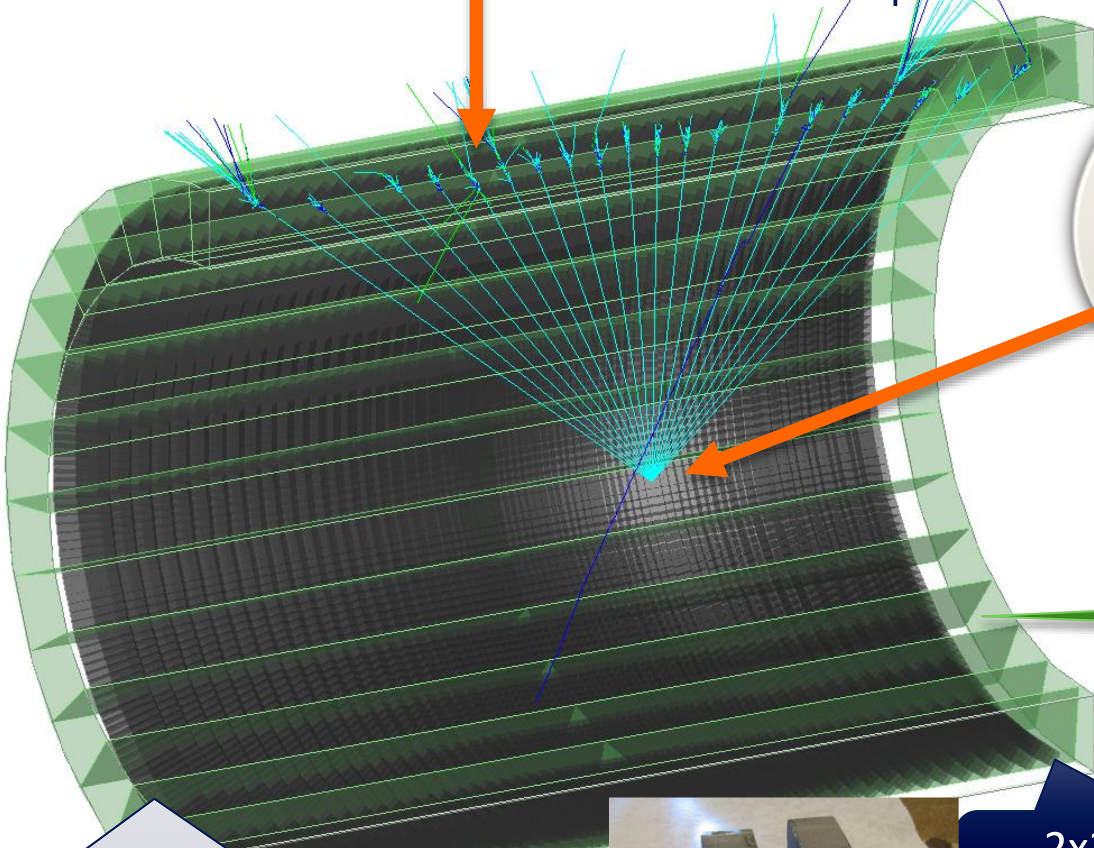
SPACAL 2D
With Birk corrections
Fully implemented 2D SPACAL

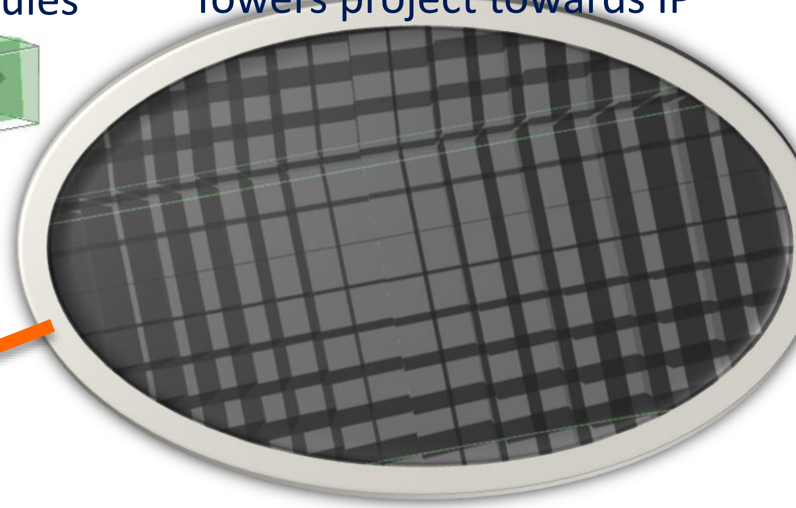
SPACAL 1D
With Birk corrections
Ideally implemented 1D SPACAL (no spt., no tower div.)



48 2x8-tower super modules

Towers project towards IP





Stainless steel SS310
Support box

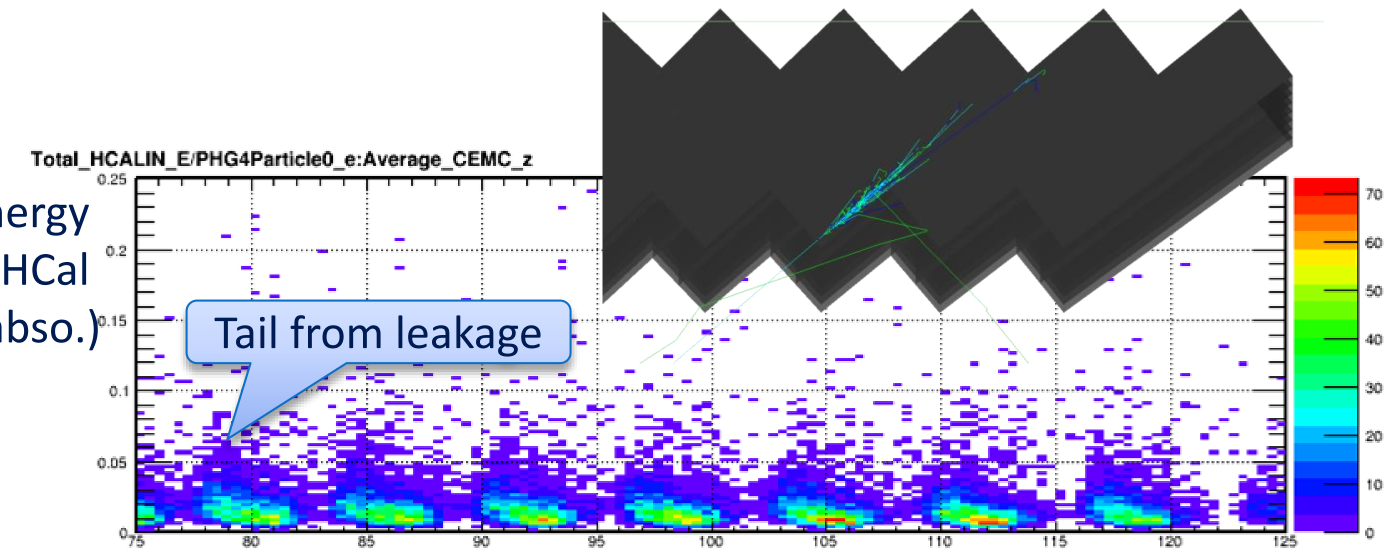
2x2 2D tapered
SPACAL modules

Gap between modules are also implemented

- 300um tolerance outside super modules skins
- ~2mil between SPACAL and SS skin
- ~2mil between SPACAL modules

Leakage looks OK so far (vs <z>). Still in verification
p_T= 4GeV/c electron in sPHENIX field

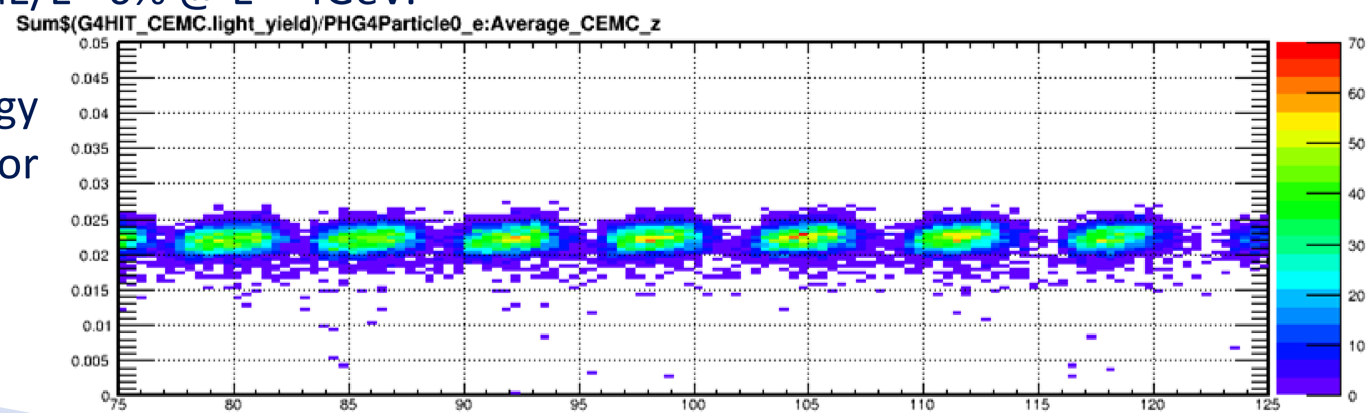
Ratio of energy in inner HCal (scint + abso.)



<z> of each shower in cm

In comparison to
energy resolution dE/E~ 6% @ E = 4GeV:

Ratio of energy in SPACAL scintillator



<z> of each shower in cm

eID and pion rejection in pp : E/p + HCal

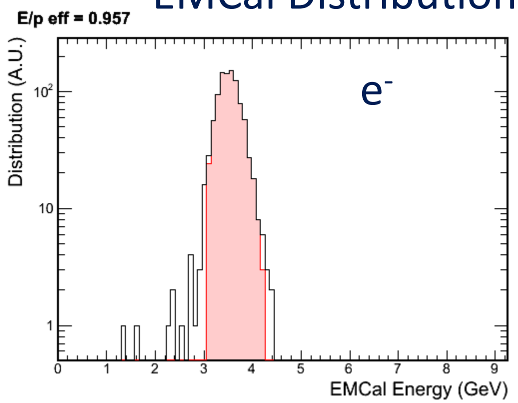
4GeV electron and pion-, |η|<0.2

EMCal tower cut : R<3cm, Hcal cut : R<20cm

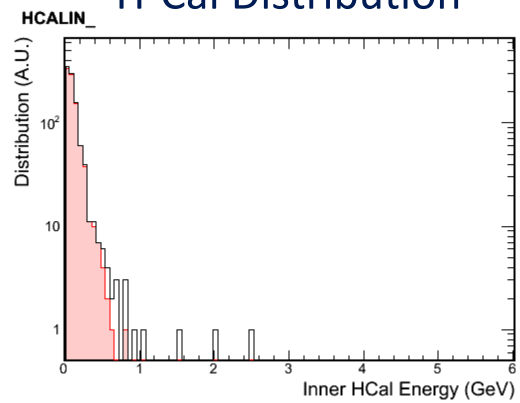
- all events

- with EMCal E/p cut

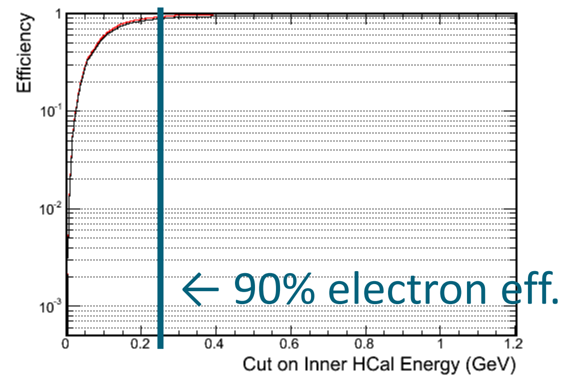
EMCal Distribution



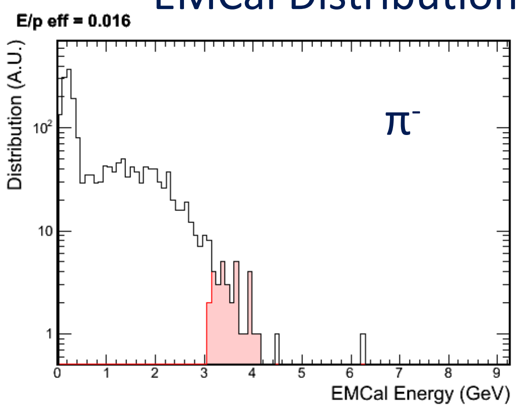
H-Cal Distribution



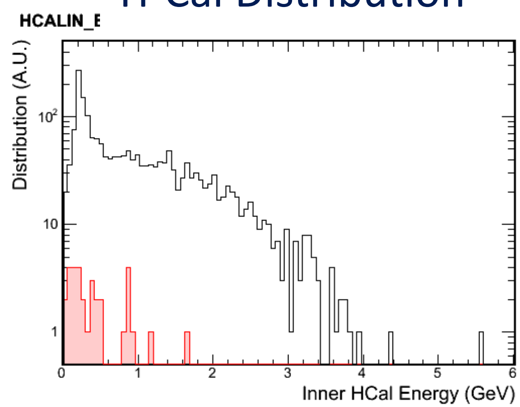
H-Cal Cut Efficiency



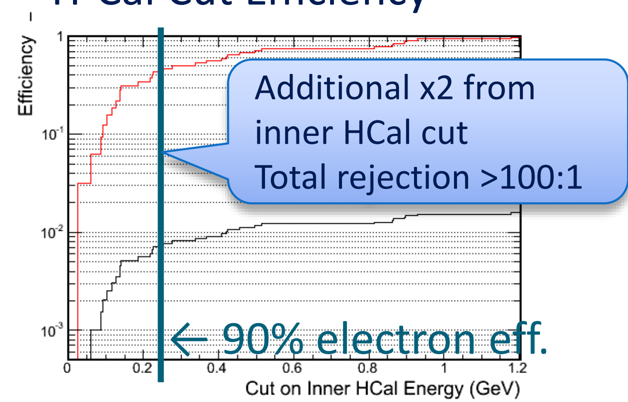
EMCal Distribution



H-Cal Distribution



H-Cal Cut Efficiency

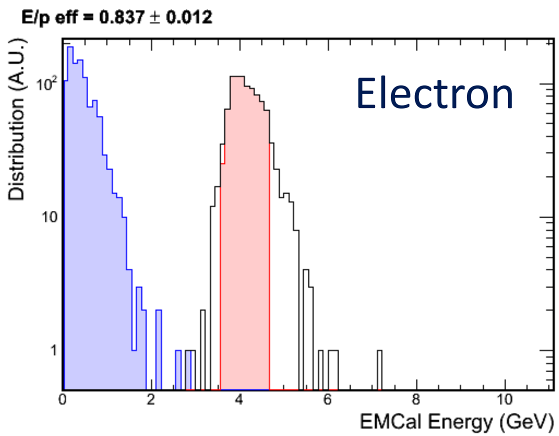


eID in central AuAu, central pseudo-rapidity

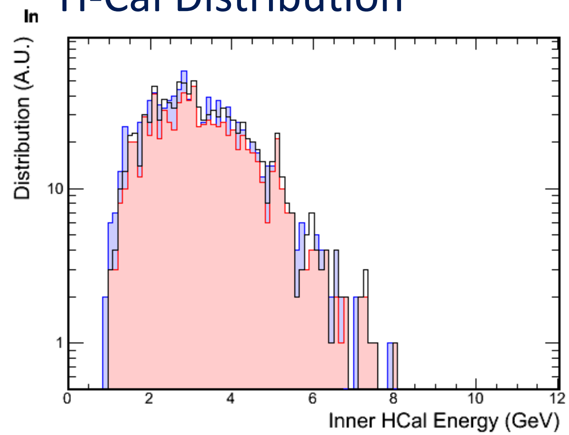
4GeV electron and pion-, |η|<0.2

EMCal tower cut : R<3cm, Hcal cut : R<20cm

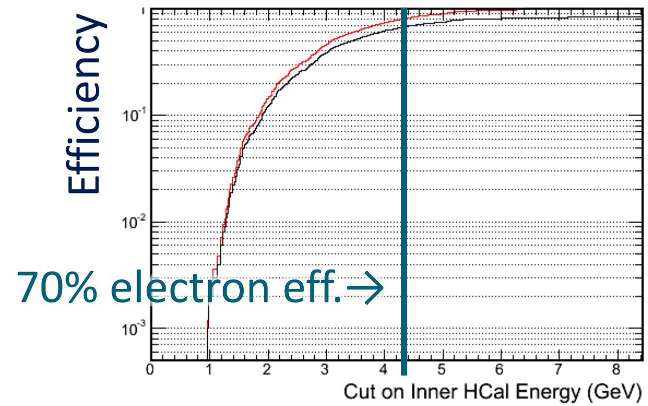
- Hijing background (AuAu 10%C in B-field)
- all c(w/ embedding)
- with EMCal E/p cut (w/ embedding)

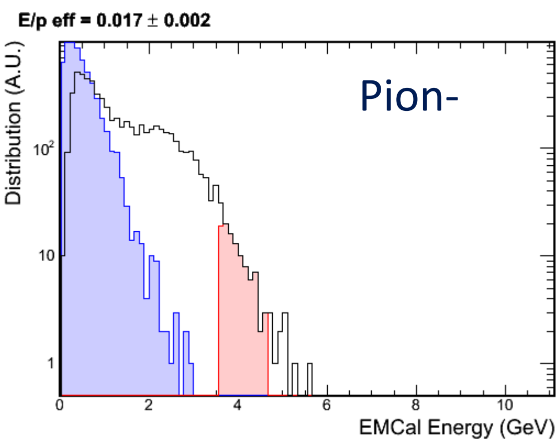


H-Cal Distribution

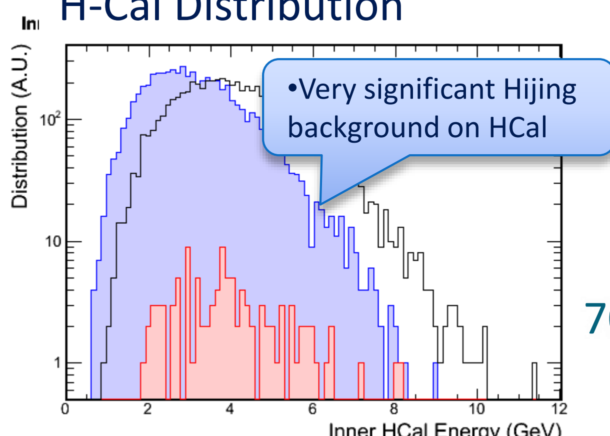


H-Cal Cut Efficiency

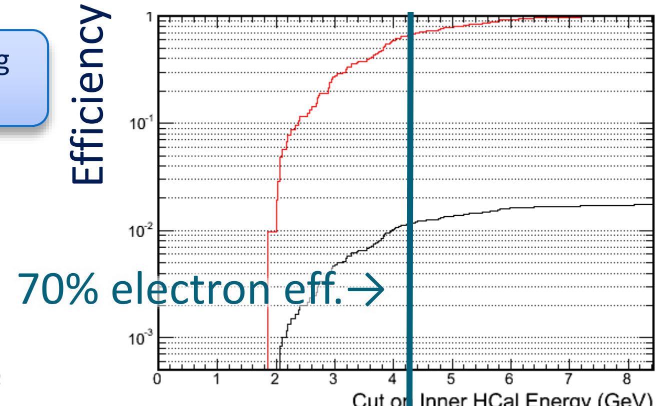




H-Cal Distribution



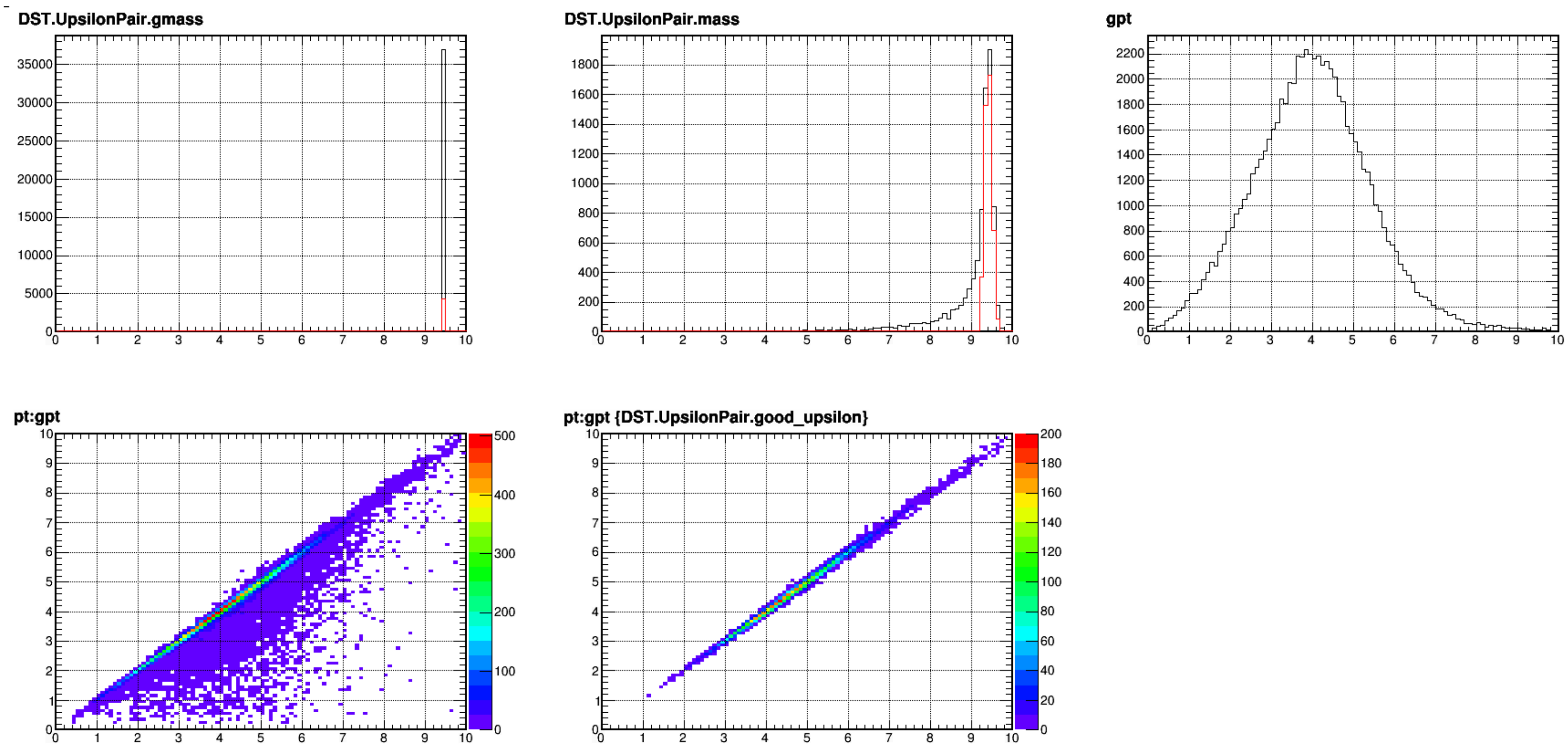
H-Cal Cut Efficiency



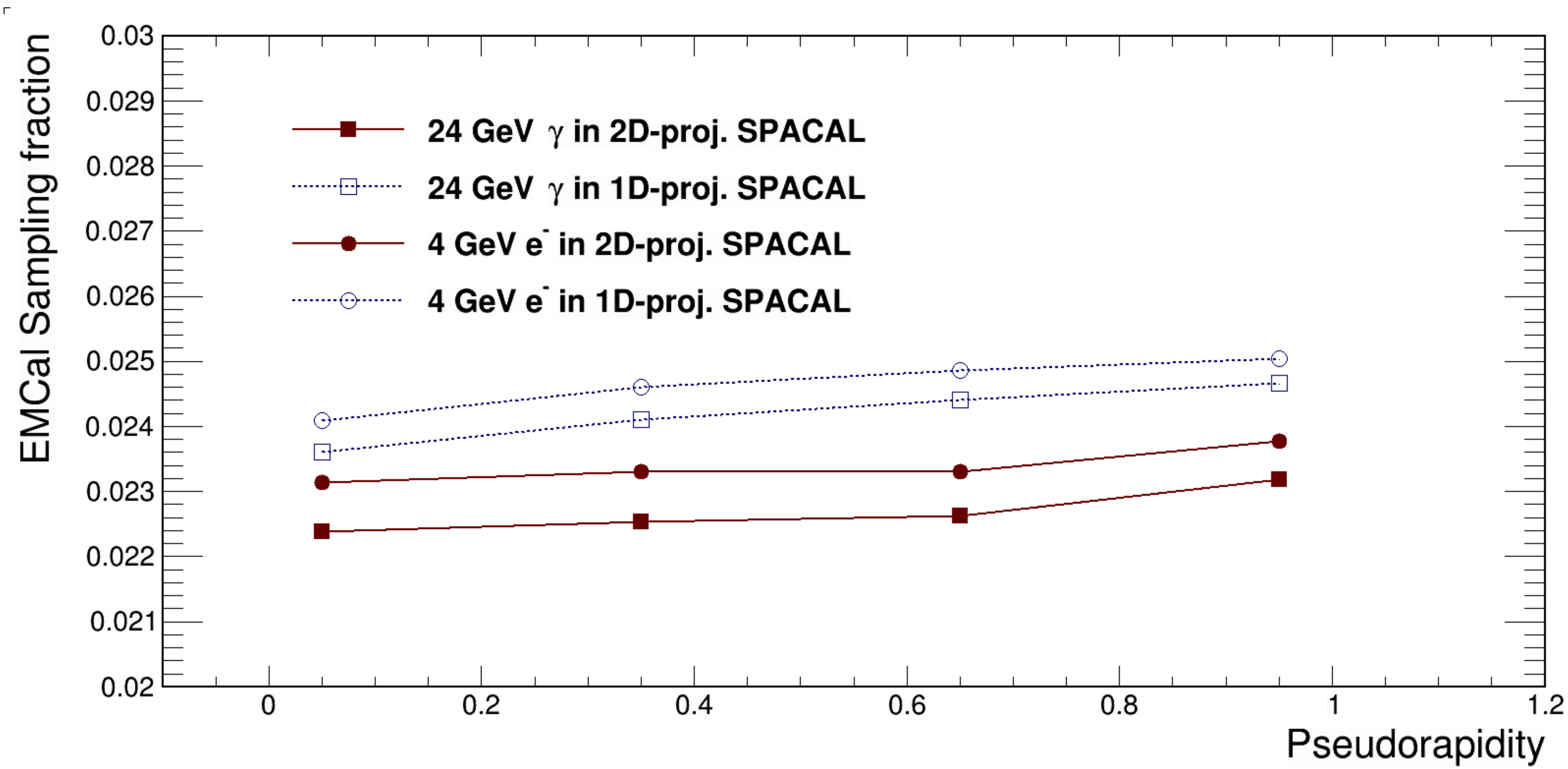
- Additional rejection of x2 from H-Cal
- **Total rejection ~90:1**

PHENIX

Upsilon simulation and selection

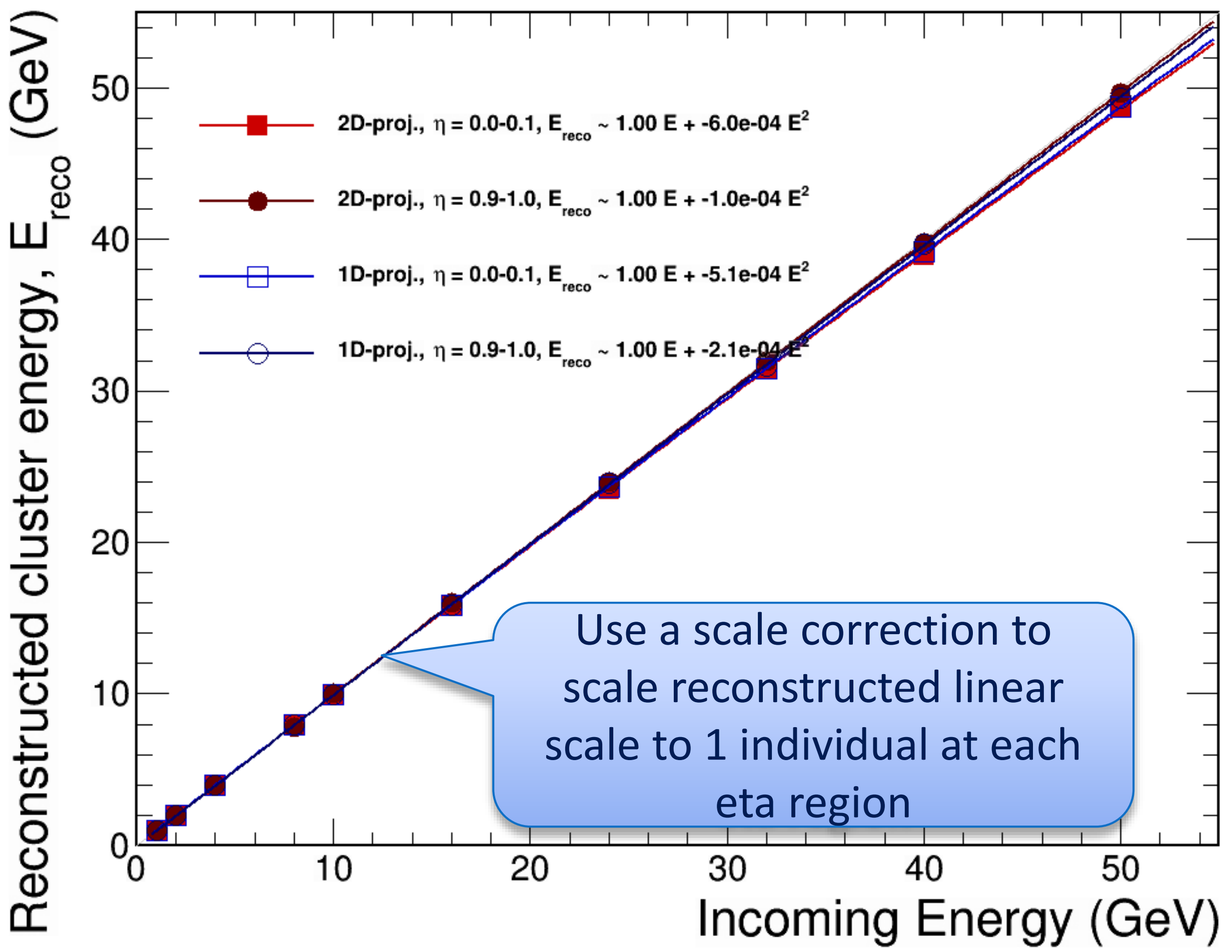


Sampling Fraction



/direct/phenix+sim02/phnxreco/ePHENIX/jinhuang/sPHENIX_work/single_particle/DrawEcal_DrawSF.pdf

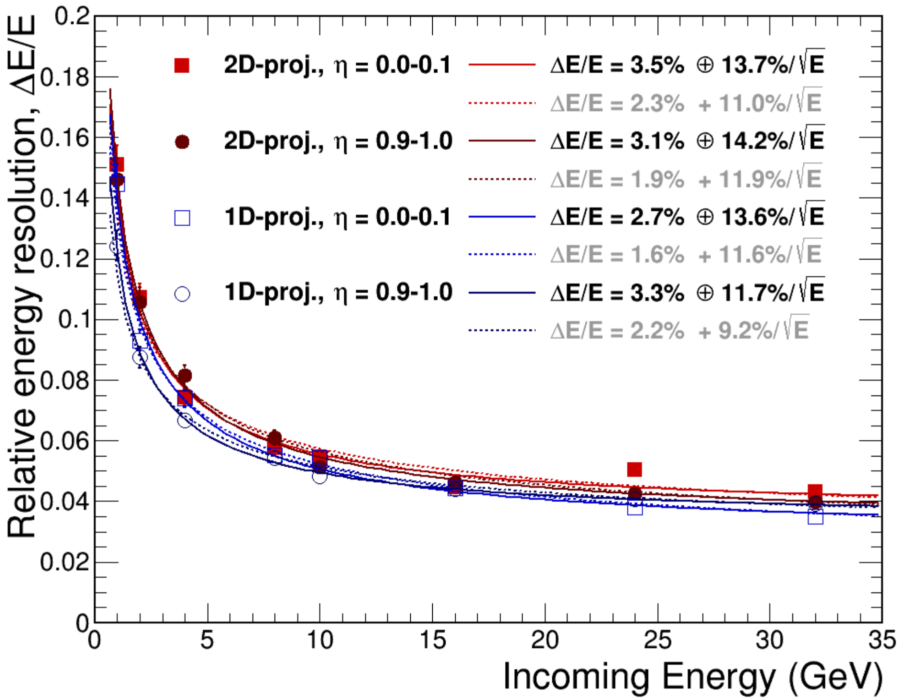
Linearality – double checking



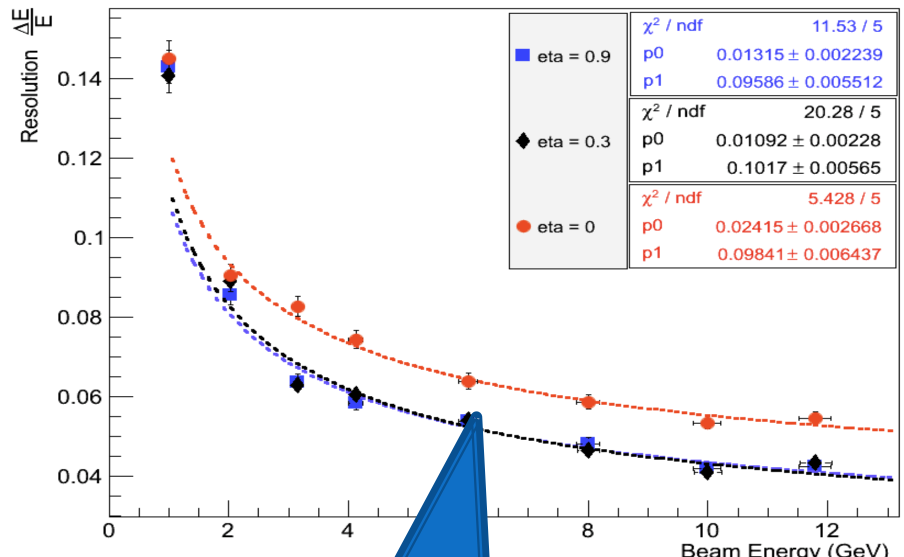
Energy resolution
Simulated with single photons

Full detector Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe), Graph clusterizer

sPHENIX full detector single photon simulation



EIC RD1 study
FermiLab beam tests



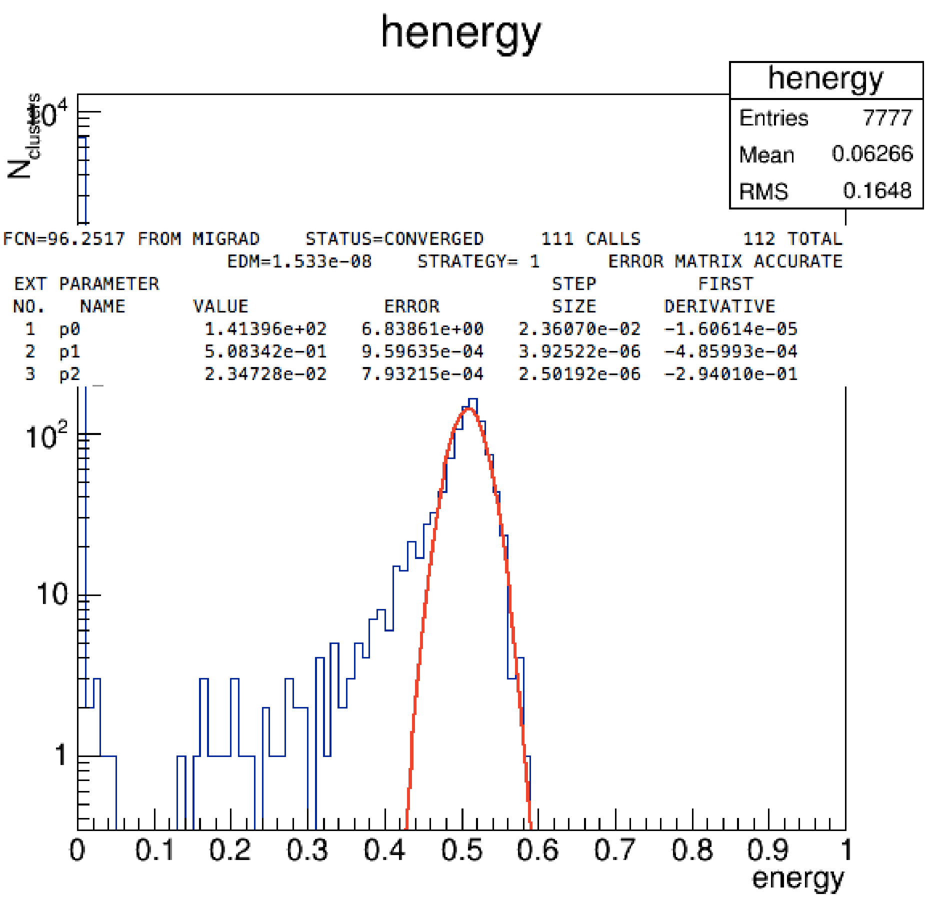
Courtesy: A.Kiselev (BNL)
DIS2014

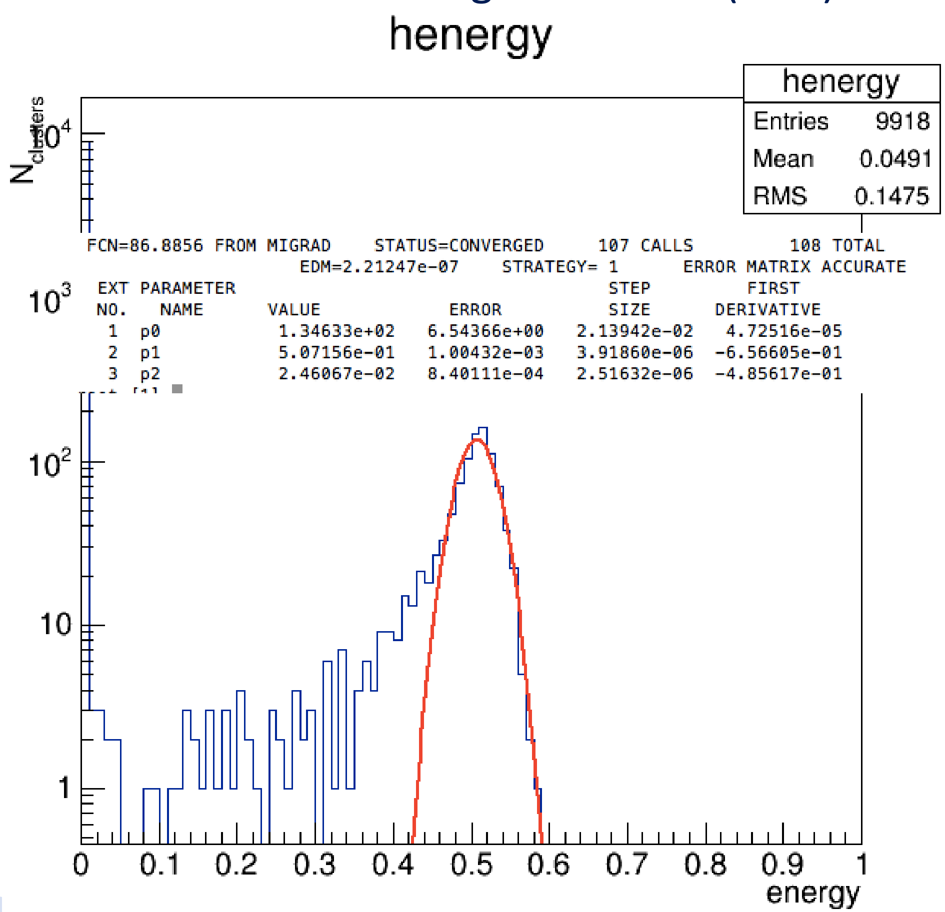
Used [1] + [2]/sqrt(E) in fit instead of sqrt sum??

Photon resolution [Megan and Stefan]

- PHENIX Clusterizer from Sasha B. survived PHENIX->sPHENIX migration.
  - Promising use of the PHENIX Clusterizer in HI embedded events
- Fit with Gaus
- [0]*exp(-0.5*((x-[1])/[2])**2)

Plots from Megan Connors (GSU)

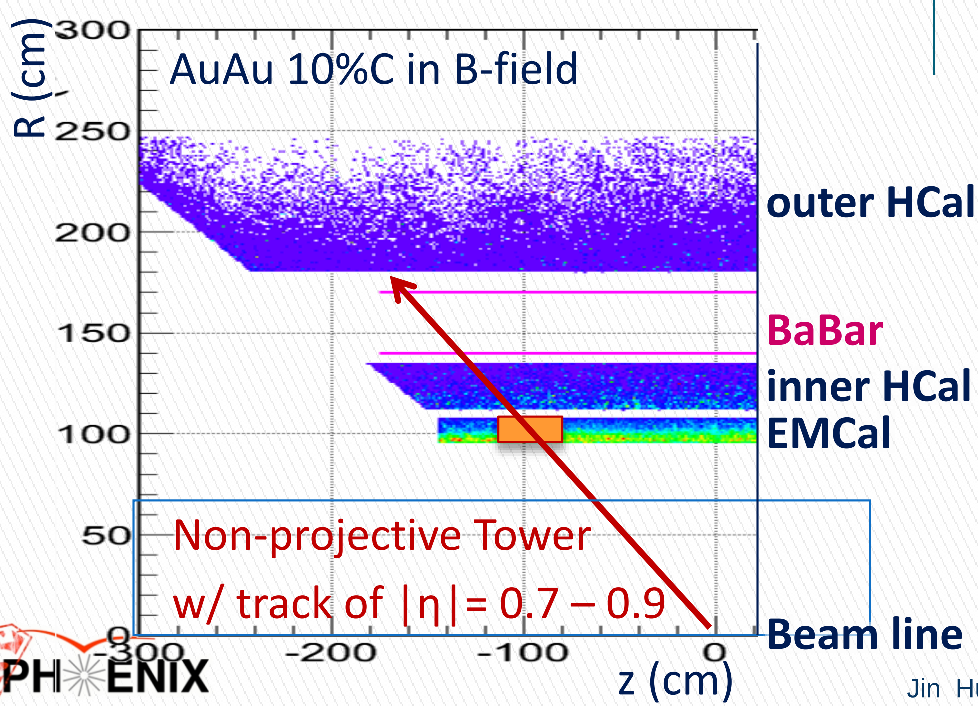




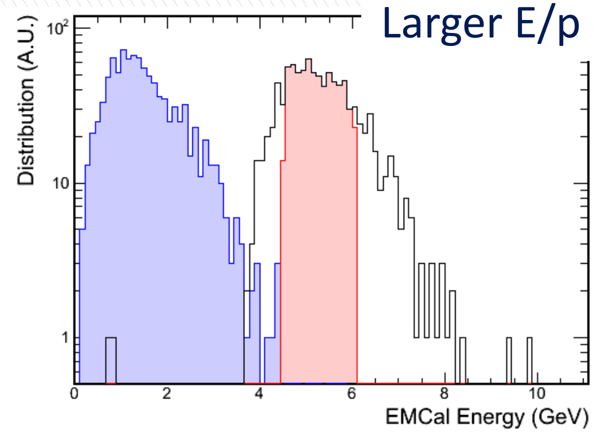
Larger pseudo-rapidity in central AuAu : under study

- Out of the box: larger |η| → larger background
  - Longer path length in calorimeter
  - Covers more non-projective towers
- Many ways to improved in near future
  - **Better estimate of the underlying background event-by-event (improve x1.5)**
  - **Use (radially) thinner ECal (improve x2)**
  - **Shower shape cuts?**
  - **Possibilities for projective towers?**

- all events (w/ embedding)
- with EMCal E/p cut (w/ embedding)
- Hijing background (AuAu 10%C in B-field)

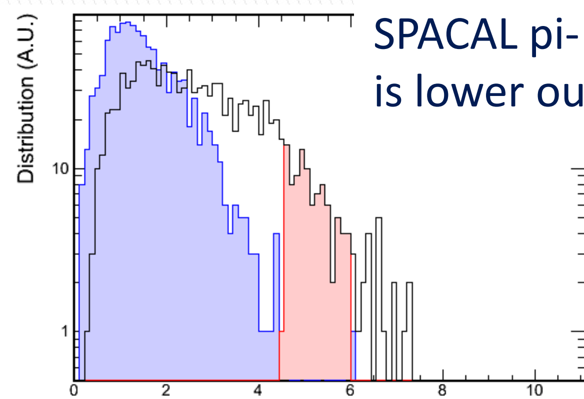


SPACAL e-
Larger E/p cuts



Out of box rejection ~10:1

SPACAL pi- rejection
is lower out of the box



Momentum distribution of Upsilon Electrons